Westar Engineering

EVALUATION AND TESTING OF WESTAR MINING LTD'S COAL TO DETERMINE ITS SUITABILITY FOR COAL WATER MIXTURE COMBUSTION (UP-W-230)

F I N A L R E P O R T

By:

DAVID M. PARKES
WESTAR ENGINEERING LTD.,
VANCOUVER, B.C.

Work on this project was conducted under the auspices of the Canada Centre for Mineral and Energy Technology, Energy, Mines and Resources, Canada.

D.S.S. File Number: 23SQ.23440-4-9009

D.S.S. Contract Serial Number: ISQ84-00014

CANMET PROJECT NUMBER:

Canmet Scientific Authority: Mr. F. Friedrich
and Mr. C. Adams

MICROMEDIA

80 pp

AUGUST 1985

TABLE OF CONTENTS

		Page No.
1.	SUMMARY	1
2.	INTRODUCTION - CARBOGEL - ECC	3
3.	ANALYTICAL METHODS - CARBOGEL - ECC	4
4.	RESULTS - CARBOGEL	5
5.	RESULTS - ENGLISH CHINA CLAYS	9
6.	DISCUSSION AND COMPARISON	11
7.	ECONOMICS	12
8.	CONCLUSIONS	13
9.	RECOMMENDATIONS	14

1. SUMMARY

This study, 75% funded by Canmet through the Department of Supply and Services, aimed to make a preliminary technical and economic appraisal of the suitability of Greenhills and Coal Creek coals owned by Westar Mining Ltd. A wholly owned subsidiary, Westar Engineering supervised the work.

AB Carbogel (ABC) of Sweden carried out bench scale tests on previously washed coal from these two mines. Both coals were easily ground (hardgrove index +85) to provide coal-water-fuel (CWF) mixtures with characteristics as follows:

	Greenhills	Coal Creek
Critical Coal Concentration	71.7%	72.3%
Ash	5.8%	4.7%
Recovery	97.3%	97.3%
Chemical Additives	up to .7%	up to 1.0%

The rather high ash in Greenhills is a disappointment, but the mixtures were stable over 2 weeks as indicated in the viscosity tests. ABC considers the CWF is likely to be suitable with concentrations 2 percentage points above the critical value.

A preliminary cost estimate shows:

Capital cost of 300,000 TPY plant	Can.$15.6 mill.
Cost of chemicals	$12.0/tonne of fuel
Operating costs	$13.0 " "
Based on coal at $37.50/tonne cost	$86.55 " "
Cost per million BTU[s]	$ 3.90

For the future ABC recommends:

- A pump study to simulate pipeline conditions.
- Investigation of production of highly loaded fuels - to 74% concentration.
- A complete feasibility of a CWF plant.

English China Clays (ECC) from St. Austell, England tested these same coals in early 1984. They reported favourably on the suitability of the coal for CWF.

	Greenhills	Coal Creek
Critical Coal Concentration	71-72%	71-72%
Additives	1-2%	1-2%
Ash	4.2%	3.6%
Recovery	89.0%	87.0%

The major difference between these results and those of ABC, is in the lower ash levels, but at considerably reduced recovery. ECC recommends a burn test to check combustion capabilities at this marginal V.M. percentage (24-27% daf).

If a commercial opportunity were in sight further testing would be recommended. However, at present, the growth is slow, oil prices are falling and Sparwood is not favourably located to existing pipelines.

SOMMAIRE

Cette étude, payée à 75% par Canmet par le reseau du Departement de Service et demandé a pour but de faire une étude préliminaire technique et economique de la validité du charbon "Greenhills et Coal Creek" appartenant à Westar Mining Ltd. Westar Engineering Ltd., une compagnie subsidiaire de Westar Mining Ltd. a supervisé les travaux.

La compagnie AB Carbogel (ABC) de la Suède ont fait quelque épreuves sur ces deux charbons lavés au preálable. Les deux charbons fusent facilement émiettés (h.i. +85) pour obtenir un mélange de charbon-eau-combustible (CWF) avec les characteristiques suivantes:

	Greenhills	Coal Creek
Concentration critique du charbon	71.7%	72.3%
Cendre	5.8%	4.7%
Rendement	97.3%	97.3%
Additif chimiques	jusqu'à 0.7%	jusqu'à 1.0%

La haute quantité de cendres dans le charbon Greenhills est un désappointement mais les mélanges furent stable pendant deux semaines tels qu'indiqués par les essais des viscosité. ABC considère que le CWF sera acceptable avec concentrations deux points de pourcentage au dessus de la valeure critique.

Une etude preliminaire du couts estime demontre:

Coût capital de 500,000 TPA (plant)	Can $15.6 million
Coût des produits chimiques	$12.0/tonne de combustible
Coût d'opération	$13.0/ " " "
Basé sur le coût du charbon à $37.50/t	$86.55/ " " "
Coût par million BTU's	$ 3.90

Pour le future, ABC recommende:

. une étude de pompes pour simuler une condition de pipeline
. un investigation de la production de combustible extremement chargé jusqu'à 74% de concentration.
. une étude complète d'un usine CWF

English China Clays (ECC) de St. Austell, Angleterre, ont conduit les mêmes essais de ces deux charbon au debut de 1984. Ils ont conclus favorablement sur l'acceptance de ces charbons pour CWF.

	Greenhills	Coal Creek
Concentration critique de charbon	71-72%	71-72%
Additifs	1-2%	1-2%
Cendres	4.2%	3.6%
Rendement	89.0%	87.0%

La différence majeure entre les résultats de ECC et ABC est dans les niveaux inférieurs de cendre de ECC, mais à rendement beaucoup plus bas. ECC recommende un essai de bruler a verifier la combustion à cette matière volatile marginalle (24-27% sans l'eau et cendre).

Si on peut voir une occasion commerciale bientôt, on recommenderait encore plusieurs autre essais. Cependent, à ce moment, l'accroisement de CWF est traînard, les prix de petroles tombent, et Sparwood se trouve très éloigné d'un pipeline.

2. INTRODUCTION

2.1 Westar Mining Ltd. has been examining alternative markets for its coal. As part of this investigation, it identified the possible substitution of oil in furnaces designed to burn oil only by a coal-water-mixture. By reducing the ash, and possibly sulphur, and by maintaining a liquid fuel, the conversion of the boiler to coal is much less expensive than converting to a dry feed process.

2.2 Previous discussions with people involved in this technology indicated that the coals at the Greenhills mine and Coal Creek exploration area would be suitable. As a first step, English China Clays (ECC) from England carried out some tests on these two coals with satisfactory results. To check these results and perform more detailed tests, Westar approached the Government Department of Supply and Services (DSS) with an unsolicited proposal for assistance in paying for this further study by AB Carbogel (ABC) in Sweden. The request was granted, with the additional request that a comparison of the results from the two organizations be included. This has been done, but regretfully, English China Clays has now closed its department devoted to such work.

2.3 The full AB Carbogel (ABC) report is included in Appendix 1. When preparing the proposal on the written recommendation of ABC, certain tests were spelled out. In checking and questioning, ABC advises that assumptions on the coal type and developments in their technology were jointly responsible for the change in scope. Tables from the English China Clays report are included in Appendix 2.

2.4 A preliminary economic assessment of the Carbogel system is also included.

3. ANALYTICAL METHODS

3.1 AB Carbogel approaches the preparation and testing of coal for coal-water-mixtures in a number of steps:

1. Crushing down to 100% minus 1 mm.
2. 2 stage flotation to reduce ash and sulphur.
3. Two grinds are carried out to determine the time of grinding to produce a particle size distribution which is known to give good concentration with reasonable demands of dispersant. They are mixed in ratios of 95/5 and again 90/10.
4. Different types and quantities of dispersants and co-surfactants are tested.
5. The critical coal concentration.
6. Changes in rheology with time is also studied.
7. Sedimentation hindering chemicals are then studied in storage at 45° C. Possible adverse gelling effects are checked.
8. Changes in viscosity were measured immediately after preparation, after 1 day, 7 days and 15 days.
9. The heat properties of the samples were tested over the same time periods.

3.2 English China Clays performed a less detailed test comprising fewer steps:

1. Crushing, grinding and screening at 75 microns.
2. Two stage flotation in ECC cells.
3. The floats were pressure filtered.
4. This cake was mixed with water. It is not clear what chemicals were used.
5. Viscosity tests using Brookfield and Ferranti methods were carried out.

4. RESULTS FROM CARBOGEL

4.1 The Carbogel results are as follows:

Analysis - Raw Coal

	Greenhills		Coal Creek	
	Westar	ABC	Westar	ABC
Ash %	7.0	7.5	6.35	6.4
V.M.% daf	27.2	27.6	25.8	24.3

Coal Concentrate Analysis - ABC

Ash%	5.8	4.7
V.M.% daf	27.0	24.6

Ultimate Analysis - ABC

Element				
C% daf	87.64		89.72	
H "	5.28		5.26	
S "	0.45	0.51	0.41	0.40
N "	0.83		1.28	
O diff % daf	5.80		3.26	

Coal Concentrate Analysis - ABC

C% daf	86.9	88.4
H "	5.0	5.0
N "	1.5	1.5
O Act % daf	6.2	4.5

4.2 The Greenhills flotation results, using chemicals as described, are given below:

Reagent	Grams added per dry tonne of feed
Frother (xo-1030)	100
Collector (xo-1032)	2,000

Recoveries	Dry Wt %	Energy %	Ash %	Sulphur %
Coal Concentrate	97.3	99.0	75.2	98.0
Tailings	2.7	1.0	24.8	2.0

Energy recovery is defined as the sum of the V.M. and Fixed Carbon on a dry ash free basis.

The concentrated and tailings were analyzed, as set out below:

	Ash %	Sulphur % d
Feed Coal	7.5	0.48
Coal Conc.	5.8	0.47
Tailings	67.3	0.34

Only 24% of the ash and 2% of the Sulphur were removed.

4.3 The Coal Creek results of flotation are given below:

Reagents	Grams added per dry tonne of feed
Frother (xo-1030)	120
Collector (xo-1032)	1,000

Recoveries	Dry Wt %	Energy %	Ash %	Sulphur %
Coal Concentrate	97.3	99.0	72.1	97.3
Tailings	2.7	1.0	27.9	2.7

The concentrate and tailings were analyzed:

	Ash % d	Sulphur % d
Coal Feed	6.4	0.38
Coal Conc.	4.7	0.37
Tailings	65.0	0.36

Only 27.9% of the ash and 2.7% of the Sulphur were removed.

4.4 Critical Coal Concentrations - the two coals were treated similarly.

	Greenhills	Coal Creek
Max. solids content of mixture ratio of grinds 95/5	74	75
Dispersant B3 grms/Kg dry coal	6	5 - 6
Critical conc.	71.7	71.9
Co-surfactants F1, F4		no effect

4.5 Sedimentation studies - stabilizers named Carbofix C13 and C14 were tried. Only C13 was effective. To hold the solids in suspension over the 2 week period, it was necessary to add the stabilizers as follows:

	Greenhills	Coal Creek
Amount of Carbofix C13 grs/Kg coal	0.56	0.69

In the test on Greenhills coal, when the amount of dispersant Carbofix B3 was increased to 7 grams per Kg, the viscocity considerably decreased with storage time.

For Coal Creek coal the minimum viscosity was found to occur when 4 grams of Carbofix B3 was added.

4.6 **General Comments:** Both coals were easy to grind with a Hargrove Index of over 85; the highest index tested to date is 75. Moderate comminution is expected in a long pipeline. No tests on this variable were done at this time.

ABC recommend that the fuel be concentrated to about 2% above the critical value because both coals are suitable for use in this way - more testing would be necessary to work out the details.

5. RESULTS - ENGLISH CHINA CLAYS

5.1 The results of the flotation and sizing are given in Table 2.

TABLE 2

Sample	% w/w Rec'y of original	Properties: % Ash	% Volatile Matter	Particle Size Microns +53	+20	+10	+5	-2	-1
Greenhills Mine									
Feed -75 microns	100	7.8		3	18	58	78	8	6
Rougher Flotation Stage									
Float Product	94	4.8							
Sink (waste)	6	54.1							
Cleaner Flotation Stage									
Float Product	89	4.2		4	17	43	89	6	4
Sink (waste)	5	17.0							
Coal Creek Mine									
Coal -75 microns	100	8.2	23.2	2	36	58	92	5	4
Rougher Flotation Stage									
Float Product	92	4.4	23.9						
Sink (waste)	8	53.4	15.1						
Cleaner Flotation Stage									
Float Product	87	3.6	24.1	4	39	50	86	3	<1
Sink (waste)	5	18.2	19.6						

5.2 The results of the slurry composition and viscosity tests are given in Table 3 below:

TABLE 3

	Greenhills Mine	Coal Creek Mine
Composition		
Coal % by weight	71-72	73-74
Additives % by weight	1-2	1-2
Remainder water		
Ash %	4.2	3.6
pH	8.4	8.6
Volatile content	-	24-25
Particle size of Solids	-75 microns	-75 microns
Viscosity at 20°C		
Brookfield 10rpm	9.5 poise	20.0 poise
20rpm	7.8 poise	16.5 poise
50rpm	6.1 poise	14.0 poise
100rpm	5.8 poise	13.0 poise
Ferranti		
11.84 sec^{-1} shear rate	5.4 poise	10.7 poise
50.67 " " "	5.5 poise	12.2 poise
125.4 " " "	7.9 poise	16.9 poise

6. DISCUSSION AND COMPARISON

6.1 It is evident that the preparation and testing of the samples by both companies was similar. The main differences in the results are in the recoveries, and ash constituents of the clean coal and waste product. The ECC tests using two stage flotation produced a cleaner product, but the efficiency of separation was not as good. See Table 6-1 below.

TABLE 6-1

	GREENHILLS		COAL CREEK	
	Carbogel	E C C	Carbogel	E C C
Coal by Wt. in CWF	71.7%	71-72%	72.3%	73-74%
Additives	.21-.7%	1-2%	upto 1%	1-2%
Particle size	-74 mic	-75 mic	-74 mic	-75 mic
Coal Rec				
Rougher F		94%		92%
Ash floats		4.8%		4.4%
Ash sinks		54.1%		53.4%
Cleaner F	97.3%	89%	97.3%	87%
Ash floats	5.8%	4.2%	4.7%	3.6%
Ash sinks	67.3%	17.0%	65.0%	18.2%

ABC, after questionning, opined that the ash levels were satisfactory. The viscosity tests were carried out in diffierent ways and cannot be directly compared. Carbogel experimented with different quantities of additives and over longer time period, so their results are more comprehensive with performance of Greenhills and Coal Creek coals resulting in similar results (0.3-0.5 Pascals). ECC show a greater range with Greenhills consistantly showing about half the values of Coal Creek in all tests.

7 ECONOMICS

Only Carbogel presented some numbers indicating the cost. These are summarised below, and can be found complete in Appendix 1.

Cost of chemicals per tonne of coal	Can.$12.00/tonne
Other operating costs	$13.00/tonne

Capital cost of a 300,000 tonne per year plant $15-16 million

With coal valued at $37.50 per ton, the cost of CWF is estimated at $86.55 per tonne or Can.$3.90 per million B.T.U.

For a 1 million tonne per year CWF plant, the capital increases to 45 million and the overall costs reduce to $80.50 per tonne or $3.63 per million BTU.

8 CONCLUSIONS

The Carbogel tests were presented by Carbogel as preliminary in nature. ABC reports both coals are suitable for CWF mixtures. However the ash content as reported by ABC at 5.8% and 4.7% are consideried high and would create heavy ash removal adjustments to the boilers. Regarding future activities, ABC suggests:

- a pump study to observe the effects of a simulated long distance pipeline.
- investigating the production of highly loaded fuels with a concentration of about 74% by adjusting the particle size distribution.
- a complete feasibility study for a CWF plant.

ECC also reports suitability of both coals to produce CWF mixtures. However their verbal recommendations at the time were for a burn test, because of concern about the borderline V.M. value.

9 RECOMMENDATIONS

In view of the narrowing margin between oil and coal prices the financial incentives to develop this new technology have diminished in recent years. The information provided by this preliminary study provides the basis for optimism that both coals are suitable for CWF treatment.

In looking ahead several years, it is perceived that a large volume market will be necessary if some of the benefits of reduced transportation costs by pipelining and tanker user are to be realised. The capital expenditure required for such a change will demand a large volume of CWF mixture. At present the market is growing slowly. Further, the location of Sparwood so far from an existing pipeline puts Westar Mining at some disadvantage compared to other locations.

The major recommendation is to continue to observe the development of this technology and the markets available for the CWF mixtures. At some future time it will likely be prudent to continue the tests to further assess the technical and economic feasibility of producing such a mixture in Sparwood.

APPENDIX 1

Carbogel

A Carbogel CWF study of the Greenhills and Coal Creek coals.

Author : Lars Gillberg

Helsingborg 1985-04-29

Håkan Malmgren and Kent Svensson carried out the slurryability experiments

Günther Simonsson made the grinding and beneficiation experiments

Content

	Page
Content	1
Summary	3
Introduction	6
Analytical methods used	
Particle size distribution	7
Solids content	7
Density	7
Rheology	7
Sedimentation stability	7
Heat properties of the fuels	7
Critical Coal Concentration	8
Coal Analytical Data	8
Results and Discussion	10
Greenhills	
Crushing and milling	10
Flotation	10
Preliminary study of types and amounts of surfactants needed to prepare fuel	11
Further studies on a new grind mixture	12
Change in viscosity with time of fuels containing no sedimentation hindering chemicals	12
Sedimentation and heat studies	13
Coal Creek	
Crushing and milling	15
Flotation	15
Preliminary study of the types and amounts of surfactants needed to prepare fuel	16

Content:

	Page
Further studies on a new grind mixture	16
Change in viscosity with time of fuels containing no sedimentation hindering chemicals	17
Sedimentation and neat studies	17
Recommendation for further work	
Pumping test	18
Highly loaded fuels	19
Feasibility study	19
Greenhills and Coal Creek Coals - Economic Evaluations	
Chemical costs	20
Plant investment costs and operations	20

Summary

The two coals studied (Greenhills and Coal Creek) were very easy to grind. They were beneficiated using froth flotation. The energy recovery was 99.0 % and the ash content of the beneficiated product was 5.8 (Greenhills) and respectively 4.7 (Coal Creek) weight %.

Both coals were easy to convert to coal water fuels, and are well suited for the Carbogel technology.

Tests were performed on fuels with the following critical coal concentrations: Greenhills 71.7 % and Coal Creek 72.3 %. The exact definition of the critical concentration is to be found on page 8 . In short it can be said that the critical coal concentration is a solids content at which the fuel studied atomize well in most CWF nozzles. It is emphasized that slurries can be produced with solids contents a couple of per cent units above the critical coal concentration. However, these fuels may not atomize well in all types of CWF nozzles.

The following amounts of chemicals were used to produce fuels stable against sedimentation during the two weeks period studied.

Beneficiation chemicals

Chemical	Grams of chemicals per ton fed raw coal (dry weight) Greenhill	Coal Creek
Frother(XO-1030)	100	120
Collector(XO-1032)	2 000	1 000

Not optimized

Carbogel

ORIGIN

Date
LG/FJ
1985-04-29

Re

Fuel chemicals

Grams of chemicals used per kg beneficiated coal (dry weight).		
Greenhill	Coal Creek	Chemical
6	5	g active substance Carbofix B3
0.7	0.7	g Carbofix A1
0.56	0.69	g Carbofix C13
2.8	2.8	g 30 % formalin

*Carbofix A1 is a deairrating agent

Fuels were produced with a solids content of 71.3 % (Greenhills) and 72.3 % (Coal Creek).

Amount of chemicals used per ton of fuel produced.		
Greenhill	Coal Creek	Chemical
4.3	3.6	kg active substance Carbofix B3
0.5	0.5	kg Carbofix A1
0.4	0.5	kg Carbofix C13
2	2	kg 30 % formalin

Upon storage the viscosity of the fuels decreased and the rheology became more pseudoplastic. Reasons for the above process, which in a way has a positive effect, are discussed in the report and studied at present.

The rheology of fuels with the above mentioned compositions are illustrated in Diagram 1 and 2.

The density of the fuels were 1.23 (Greennill) and respectively 1.21 (Coal Creek) g/cm^3.

Recommendations for further work is found on page 18 .

Some initial guidelines of the costs involved for the conversion of the Greennill and Coal Creek coals to Carbogel is found on page 20.

Introduction

The procedures AB Carbogel uses to test the slurryability of coals consists of the following parts:

1. First is studied how the coal shall be ground to get a particle size distribution which is known to give reasonable high solids loadings at resonable demands of dispersant.
2. Two grinds are produced.
3. A beneficiation study is carried out.
4. The two grinds are mixed in the proportion giving the previously mentioned particle size distribution.
5. The type and amounts of dispersants needed to prepare a concentrated fuel is determined. The effect of different co-surfactants is also tested.
6. The critical coal concentration is determined.
7. A larger batch of a new grind mixture is prepared.
8. The critical coal concentration and the amount of dispersant to convert the grind to a fuel is determined.
9. The amount of dispersant needed to prepare a fuel at its critical coal concentration is determined.
10. The change in rheology with time of a sample containing two different amounts of dispersant is studied.

    Now the amount and types of dispersant to prepare an easily atomizable fuel is known. As the fuel is well dispersed it will tend to sediment.

11. The effect of the addition of different types and concentrations of sedimentation hindering chemicals is then tested. The rheology, sedimentation properties and possible gelling effects obtained at prolonged storage at 45 ^{o}C is then studied.
12. The type and amount of chemicals needed to prepare a fuel stable agains sedimentation is established.

Analytical Methods used

Particle size distribution

The particle size distribution was analysed with 3-tubes Coulter Counter technique.

Solids content

The solids content was analysed by drying the sample to constant weight on a balance equipped with an infrared radiation unit.

Density

The density of the fuels were determined by weighing 100 ml fuel in a graduated cylinder.

Rheology

The rheology was assessed at 25°C using Contraves Rheomat 115. This is a rotational viscometer. The DIN-normalized measuring system 125 was used. This system has a gap width of 1.06 mm.

The sample was accelerated during 2.24 minutes from 0 to 452 s^{-1}. The shear rate was kept constant at 452 s^{-1} during 5 minutes and then decellerated to 0 s^{-1} during 2.24 minutes.

Sedimentation stability

The sedimentation stability was tested during a two weeks period.
150 grams samples were transported in a car. The sedimentation properties were investigated with a spoon. The scale used is printed on the diagrams.

Heat properties of the slurries

100 grams samples were kept in a sealed container at 45°C. The properties of the fuels were investigated during a period of 14 days. The scale used is printed on the diagrams.

Carbogel

ORIGIN

Date
LG/FJ
1985-04-29

Re:

Critical coal concentration

The critical coal concentration (CCC) is the solids content (weight % solids) at which the viscosity measured at 452 s^{-1} during the acceleration phase increases with 0.1 Pas when the solids content of the fuel increases with 1 % (e.g. from 70 to 71%).

The higher the CCC the more coal the fuel contains. The CCC depends on the type of coal used (especially its porosity and surface characteristics), the particle size distribution of the grind and the geometry of the particles.

Fuels with a solids concentration around the critical coal concentration spray good in most atomization nozzles. Many good nozzles can atomize Carbogel with solids concentration above the critical coal concentration.

Coal Analytical Data

PROXIMATE ANALYSIS

The raw coals had the following analytical data

	Weststar analysis		ABC-analysis	
	Greenhill	Coal Creek	Greenhill	Coal Creek
Ash	7.0 %d	6.35 %d	7.5 %d	6.4 %d
Volatile matter	29.2 %daf	25.8 %daf	27.6 %daf	24.3 %daf

The coal concentrates had the following analytical data

	Greenhill	Coal Creek
Ash	5.8 %d	4.7 %d
Volatile matter	27.0 %daf	24.6 %daf

Carbogel

ORIGIN

Date
LG/FJ
1985-04-29

Re

ULTIMATE ANALYSIS

The raw coals had the following analytical data.

Element	Weststar analysis % daf		ABC analysis % daf	
	Greenhill	Coal Creek	Greenhill	Coal Creek
C	87.64	89.72	-	-
H	5.28	5.26	-	-
S	0.45	0.41	0.51	0.40
N	0.83	1.28	-	-
O(diff)	5.80	3.26	-	-

The coal concentrate had the following analytical data.

Element	% daf	
	Greenhill	Coal Creek
C	86.9	88.4
H	5.0	5.0
N	1.5	1.5
O(actual)	6.2	4.5

Results and Discussion

GREENHILL

Crushing - milling

The coal was crushed to a size about -1 mm. The crushed product was coned and quartered six times and then milled in the laboratory mill during 3 minutes. The milled product was sieved through a sieve with 200 microns openings. The + 200 micron portion was milled in another laboratory mill during 40 minutes. The two grinds were beneficiated by froth flotation.

Flotation

The grinds were mixed in the dry weight ration 95/5. They were beneficiated by flotation (3 cyclic test procedure) and the following amounts of chemicals were used :

Chemical	grams chemical added per ton fed coal (dry weight)
Frother(XO-1030)	100
Collector(XO-1032)	2 000

The following recoveries were obtained

Product	Recovery Dry weight %	Energy %	Ash %	Sulphur %
Coal concentrate	97.3	99.0	75.2	98.0
Tailings	2.7	1.0	24.8	2.0

The energy recovery is defined as the recovery of volatile matter + Carbon fix on dry ash free basis.

The ash and sulphur contents of the products were

Product	Ash content %	Sulphur content %
Original coal	7.5	0.48
Coal concentrate	5.8	0.47
Tailings	67.3	0.34

From the tables it can be seen that 24.8 % of the ash was removed. The energy recovery was 99.0 %. Only 2 % of the total sulphur was removed. The relation between organic and pyritic sulphur was not analysed.

The beneficiation study shall be considered as an indicative study on the beneficiation results which can be obtained. One frother/collector system was tested. The use of other type of collector systems may result in reduced retention times and decreased amounts of collector needed.
The energy recovery is expected to be about the same with other collector systems. If the presented energy recovery and ash and sulphur contents in the concentrate are satisfactory to Weststar, AB Carbogel, will, on request, free of charge carry out an optimization study on the collector system.

Preliminary study of types and amounts of surfactants needed to prepare fuel.

The two previous mentioned grinds were mixed in the weight relationship 95/5. Diagram 3 illustrates the particle size distribution of the mixture.
Fuels with solids contents around 74 % were prepared using different amounts of Carbofix B3 as dispersant. The viscosity minimum was obtained at a surfactant concentration of 6 grams of active substance per kg dry coal.(See Diagram 4).
The fuel was diluted with water in increments and the rheology of the fuels were measured (for results see Diagram 5).
The critical coal concentration of this grind was found to be 71.7 % (see Diagram 6).
As co-surfactant were tested Carbofix F1 and F4. These co-surfactants had no positive effect (see Diagram 6).

Further studies on a new grind mixture

Two new grinds were produced and mixed in the weight ratio 90/10. Diagram 7 illustrates the particle size distribution of the grind.
Fuels were produced at a solids content around 73.5 % using different amounts of Carbofix B3 as dispersant. (For details see Diagram 8). The viscosity minimum was found to be obtained at a concentration of 6 grams active substance of Carbofix B3 per kg of dry coal. The fuel with this concentration of Carbofix B3 was diluted with water in increments and the rheology of the fuels were measured (for results see Diagram 9). The critical coal concentration was found to be 71.0 % (see Diagram 10).

Fuels were prepared from the same grind at a solids content around 71 % and using different amounts of Carbofix B3. Viscosity minimum was found to be obtained with a dispersant concentration of 5 grams of active substance per kg dry coal (see Diagram 11 for details).

Change in viscosity with time of fuels containing no sedimentation hindering chemicals.

From the same grind mixture, fuels were prepared with a solids content of 71.7 % using 5 and respectively 7 grams active substance of Carbofix B3 as dispersant. The viscosity of the fuels were measured immediately after preparation and after homogenization 1, 7and respectively 15 days after the preparation of the fuels. Diagrams 12 and 13 illustrate the results.
From Diagram 12 it can be seen that the viscosity of the sample containing 5 g a.s. Carbofix B3/kg coal increased with time (N.B. the solids content (SC) of the sample stored for 7 days was 71.4 % as compared to 71.7 % for the samples stored 0 and 1 days. To make a proper comparison with the other two curves the viscosity curve of the sample stored for 7 days should be elevated somewhat).

Pore penetration of the surfactant can be a reason for the viscosity increase of the fuel with time. From Diagram 12 it is clear that 5 grams a.s. of Carbofix B3 is a too low amount of dispersant for the grind mixture used.

From Diagram 13 it can be seen that when the fuel contained 7 grams a.s. Carbofix B3 per kg of coal the fuel viscosity decreased with increased storage time. The effect was quite pronounced.

At present, reasons for the effect is under investigation. The coal is very soft and one reason would be that the coal is ground to a particle size distribution giving a lower fuel viscosity when it was homogenized. Another reason would be that the coal contains sites to which Carbofix B3 adheres slowly only. Results of these investigations will be ready first after the time period at which this report should be ready.

Anyhow the curves in Diagram 13 show that 7 grams active substance of Carbofix B3 per kg coal was a sufficiant amount dispersant to slurry the grind mixture.

Sedimentation and heat studies

Two sedimentation hindering chemicals (stabilizers) were tested (Carbofix C13 and Carbofix C14). Carbofix C14 did not work well on the two Weststar coal tested. Only results using Carbofix C13 are reported.

From the previous grind mixture a larger batch of fuel was produced using 6 grams a.s. of Carbofix B3 as dispersant. Various amounts of Carbofix C13 was added. The solids content of the fuels were around 71.4 %. The sedimentation properties of the fuels were studied over a two weeks period. The results are illustrated in Diagram 14. From the diagram it can be seen that 0.56 grams of Carbofix C13 per kg coal was sufficiant to obtain sedimentation stability over the period studied.

The properties of the fuels stored at a temperature of 45 ^{o}C were also studied. The results are illustrated in Diagram 15. From the Diagram it can be seen that the fuels tolerated the storage at 45 ^{o}C very well.

The viscosities of the fuels containing 0.56 and 0.70 Carbofix C13 were measured one and respectively 14 days after preparation. The results are illustrated in Diagram 16.

From the diagram it can be seen that the viscosity of the fuels decreased considerably with time and that the acceleration curve got a more pronounced pseudoplastic behaviour with time. The reason for this effect may be due to the same dispersion promoting effect with time as previously discussed in conjunction with Diagram 13.

If the above maturation phenomenon is a serious problem it is suggested that further studies are carried out in order to try to minimize the problem.

COAL CREEK

Crushing - milling

The same procedure was used as described for the Greenhill Coal. The milling times were 5 and respectively 40 minutes.

Flotation

The coarse and fine grind were mixed in the weight ratio 90/10. They were beneficiated by flotation using a 3 cyclic test procedure. The following amounts of chemicals were used :

Chemical	grams of chemical added per ton of coal (based on its dry weight)
Frother(XO-1030)	120
Collector(XO-1032)	1 000

The following recoveries were obtained

	Recovery			
Product	Dry weight %	Energy %	Ash %	Sulphur %
Coal concentrate	97.3	99.0	72.1	97.3
Tailings	2.7	1.0	27.9	2.7

The energy recovery is defined as the recovery of volatile matter + C_{fix} on dry ash free basis.

The ash and sulphur contents of the products were (dry weight basis) :

Product	Ash content %	Sulphur content %
Original coal	6.4	0.38
Coal concentrate	4.7	0.37
Tailings	65.0	0.36

From the tables it can be seen that 27.9 % of the ash was removed. The energy recovery was 99.0 %.

Also in this case the beneficiation study shall be considered as an indicative study on the beneficiation that can be obtained.One frother/collector system was tested. The use of other types of collector systems may result in reduced retention times and decreased amounts of collector needed. The energy recovery is expected to be about the same with other collector systems. If the presented energy recovery and ash and sulphur contents in the concentrate are satisfactory to Weststar, AB Carbogel will, on request, free of charge carry out an optimization study of the collector system.

Preliminary study of the types and amounts of surfactants needed to prepare slurries.

A grind mixture was made. The particle size distribution of the mixture is illustrated in Diagram 17.

Fuels with a solids content of about 75 % were prepared with different amounts of Carbofix B3 as dispersant. The viscosity minimum was found to be at a dispersant concentration of 5 to 6 grams a.s. of Carbofix B3 per kg of dry coal (see Diagram 18).
The critical coal concentration of this grind was found to be 71.9 % (see Diagram 19). As co-surfactants were tested Carbofix F1 and F4. They had no viscosity decreasing effect (see Diagram 19).

Further studies on a new grind mixture

Another grind mixture was produced. The particle size distribution is illustrated in Diagram 20.

Fuels were produced with a stolids content of 75.2 % using different amounts of Carbofix B3 as dispersant. The viscosity minimum was found to occur around a dispersant concentration of 6 grams a.s. of Carbofix B3 per kg coal (see Diagam 21). The fuel with this surfactant concentration was diluted in increments.The viscosities of the samples were assessed (see Diagram 22) and the critical coal concentrations was found to be 72.3 % (see Diagram 23).

From the same grind mixture fuels were prepared at the critical coal concentration using different amounts of Carbofix B3. Viscosity minimum was found to occur with a Carbofix B3 concentration of 4 g per kg dry coal (see Diagram 24 for details).

Change in viscosity with time of fuels containing no sedimentation hindering chemicals

A fuel was produced at a solids content of 72.4 % using 4 and respectively 6 g a.s. Carbofix B3 per kg coal as dispersant. The rheology of the fuels were measured immediately, 1, 7 and 14 days after the preparation. The results are illustrated in Diagram 25 and 26. From Diagram 25 it can be seen that the viscosity of the sample containing 6 grams active substance Carbofix B3 per kg coal decreased considerably between 1 and 7 days after the preparation of the fuel. In this respect it behaved in the same way as the Greenhill Coal fuel containing 7 grams active substance of Carbofix B3 per kg of coal.
The effect of the coal Creek fuel seems however to occur somewhat faster than the effect with the Greenhill fuel.
From Diagram 26 it can be seen that the fuel viscosity increased with time if the fuel only contained 4 grams active substance of Carbofix B3 per kg coal.

From Diagram 25 and 26 it can be concluded that 6 grams of Carbofix B3 was sufficiant and 4 grams of Carbofix B3 was too small amount of dispersant to produce a fuel from the grind mixture.

Sedimentation and heat studies

From the grind mixture a batch of fuel was produced with a solids content of 72.4 % using 5 grams active substance of Carbofix B3 per kg dry coal as dispersant. Various amounts of Carbofix C13 were added to aliquots of the fuel. The Carbofix C13 concentrations tested were 0.42; 0.55; 0.69 and respectively 0.83 g Carbofix C13 per kg coal (on dry basis).
Some of the sample were stored at 45^{o}C. The heat properties of all samples were excellent as can be seen from Diagram 27. The sedimentation properties are illustrated in Diagram 28. From the Diagram it can be seen that the fuels were stable against sedimentation when the fuels contained 0.69 g Carbofix C13 per kg coal.

The rheology of the samples containing 0.55 and respectively 0.69 g Carbofix B3 per kg coal were measured 1 and 16 days after the preparation. The results (acceleration curves) are illustrated in Diagram 29. From the diagram it can be seen that the viscosity of the fuels decreased considerably with time and that the acceleration curve got a more pseudoplastic behaviour with time. In this respect the Coal Creek fuels behaved similarily to the fuels prepared from the Greenhill coal. The reasons for this effect are assumed to be of the same type.

Recommendations for further work

Pumping test

As the coals were very easy to grind (the Hardgrove index was 85 +), there are reasons to believe that the particles in the fuel will be comminuted on prolonged pumping of the fuel. This will result in an increased amount of small particles, leading to an increased particle area. In order to maintain a low viscosity of the fuel an extra amount of dispersant (Carbofix B3) has to be added to the slurry to reduce the adverse effects of the comminution process. So far the experiences of pumping Carbogel longer periods of time is limited to fuels produced from coals with Hardgrove indices of 75 and lower. Carbogel produced from the coal with a Hardgrove index of 75 was pumped over 2 000 hours. Extra dispersant was added after around each 200 (occasionally up to 300) hours pumping time. As a comparison it can be said that the resident time for the slurry in the Black Mesa pipeline in the USA is below 100 hours.

In order to study how long time a Greenhill or Coal Creek fuel containing different concentrations of dispersant can be pumped, the effect of extra addition of dispersant during the pumping period and the influence of the pumping time on the particle size distribution a pump study is suggested. Carbogel would be happy to carry out such a study.

Highly loaded fuels

Both the Greenhill and the Coal Creek coals are well suited for the production of very highly loaded fuels. By changing the particle size distribution, fuels with a critical coal concentration around 74 % relatively easily can be produced. The production of this type of fuel will require substantially higher amounts (around 40-50 %) of dispersant (Cardofix B3). If Weststar is interested in producing very highly loaded fuels, work should be started in this area. It is emphasized that fuels can be manufactured with solids content around 2 % units above the critical coal concentration. The production parameters for such a fuel must however be stricly controlled.

Feasibility study CWF plant

During the next phase of the Weststar CWF evaluations a feasibility study re Carbogel fuel manufacturing needs to be performed. Some economic evaluations have been included in this report for initial guidance (next section in this report).

Greenhills and Coal Creek Coals - Economic evaluations

Chemical costs

Carbogel fuels were produced with solids concentration between 71 - 75 % coal. Use of chemicals were in line with predictions based on similar types of feedstocks.

The actual costs for the chemical system (based on todays cost of production in small quantities) are as follows :

Carbofix B3 : Can $ 2/kg active substance. As an average 4 kg was used.
Total cost Can $ 8/ton fuel

Carbofix C13: Can $ 6/kg active substance. 0.5 kg was used.
Total cost Can $ 3/ton fuel

Costs for other chemicals i.e. beneficiation, antifoam etc. amount totally to Can $ 1.

Total costs based on todays chemical rates Can $ 12/ton fuel.

Plant investment costs and operations

This summary covers a recent performed study in respect to Plantinvestments and operating costs for a new Carbogel manufacturing plant.

a) Assumptions

- production capacity 300 000 tons/year
- fuel specification
    - minimum coalcontent 70 %
    - ash level 5 %
    - minimum calorific recovery 95 %

- sizing of the plant is defined from
  normal production 24 hours /day
  5 days/week
  48 hours/year
- availability factor 90 %
- design capacity 110 % of normal
- total number of employees to staff a complete dedicated organization totals 50
- cost of chemicals have been included at todays actual cost. Improvements are anticipated at higher production volumes
- plant to operate completely independant

b) plant investments Can $ million

- site area	0.3
- raw materials handling	0.9
- grinding	1.4
- beneficiation (flotation)	1.0
- dewatering	1.1
- mixing	0.7
- storage	1.2
- waste dewatering equipment	0.3
- maintenance	0.2
- administration and laboratory facilities	0.7
- construction costs	3.4
- electrical equipments	1.0
- spare parts	0.4
- design costs	1.2
- miscell. and contingency (10%)	1.8
	Can $ 15.6 m

c) operation costs

	Can $/tonne Carbogel
- personnel	4.60
- electricity	2.00
- water	-
- grinding media	0.80
- chemicals	12.00
- maintenance spares	0.60
- licence fees, miscellaneous wheel loaders contingencies	5.00
total operating	25.00

d) summary of costs for a 300 000 TPA plant

assumptions

- raw coal feed cost has been utilized at 40 dollars, 45 dollars and 50 dollars respectively
- capital charge and depreciation - assumed at 15 % per annum (10 years)
- power consumption kw hr/ton Carbogel CWF = 58
- coal or CWF transportation costs included at Can $20/tonne delivered
- CWF calorific value 10 000 BTU/lb

	Cost per ton CWF Dollar Canadian	Dollars Canadian	Dollars Canadian
Coal at 0.75 T/ton CWF	30.00/coal 40	33.75/coal 45	37.5/coal 50
Transportation	20.00	20.00	20.00
Operating costs	25.00	25.00	25.00
Capital charge and depreciation	7.80	7.80	7.80
Cost Can $/ton CWF delivered	82.80	86.55	90.30
Cost CWF/million BTU	3.73	3.90	4.07

Carbogel

ORIGIN

Date
LG/FJ
1985-04-29

Re

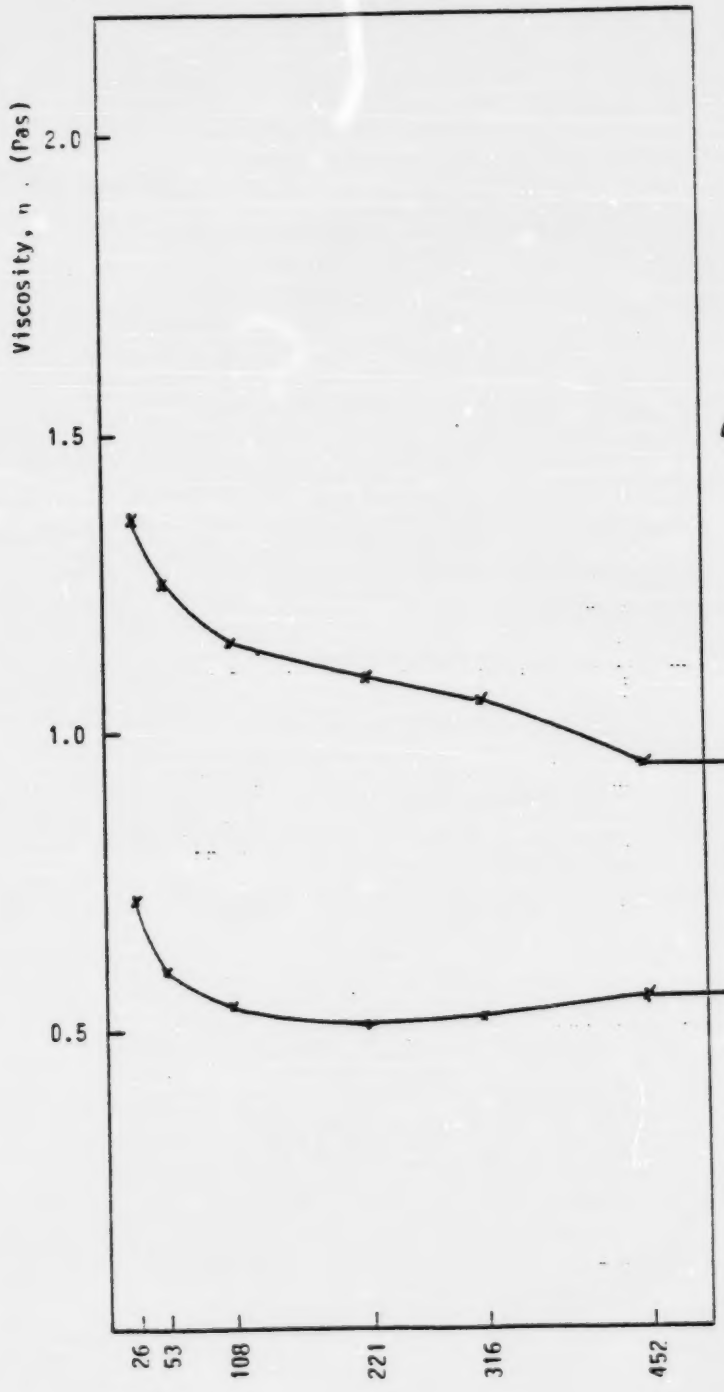
e/ summary of costs for a 1 million TPA plant assumptions :

- capital investment for plant 45 million Dollars Canadian
- operating costs Can $ 20 / ton CWF
- other assumption equal to above

	Cost per ton CWF		
	Dollars Canadian	Dollars Canadian	Dollars Canadian
Coal at 0.75 T/ton CWF	30.00	33.75	37.50
Transportation	20.00	20.00	20.00
Operating costs	20.00	20.00	20.00
Capital charges	6.75	6.75	6.75
Cost CAN $/ton CWF delivered	76.75	80.50	84.25
Cost CWF/million BTU	3.46	3.63	3.80

Carbogel — THE INFLUENCE OF THE SHEAR RATE ON THE VISCOSITY — Diagram 1

COAL	DATE	NOTES
Green Hill	850427	Rheology measured after 14 days storage
MEASURING SYSTEM	SIGN	
DIN-125	H. M.	



Note:
- Dispersants
- Solids content
- Density
- Stabilizer
- Others

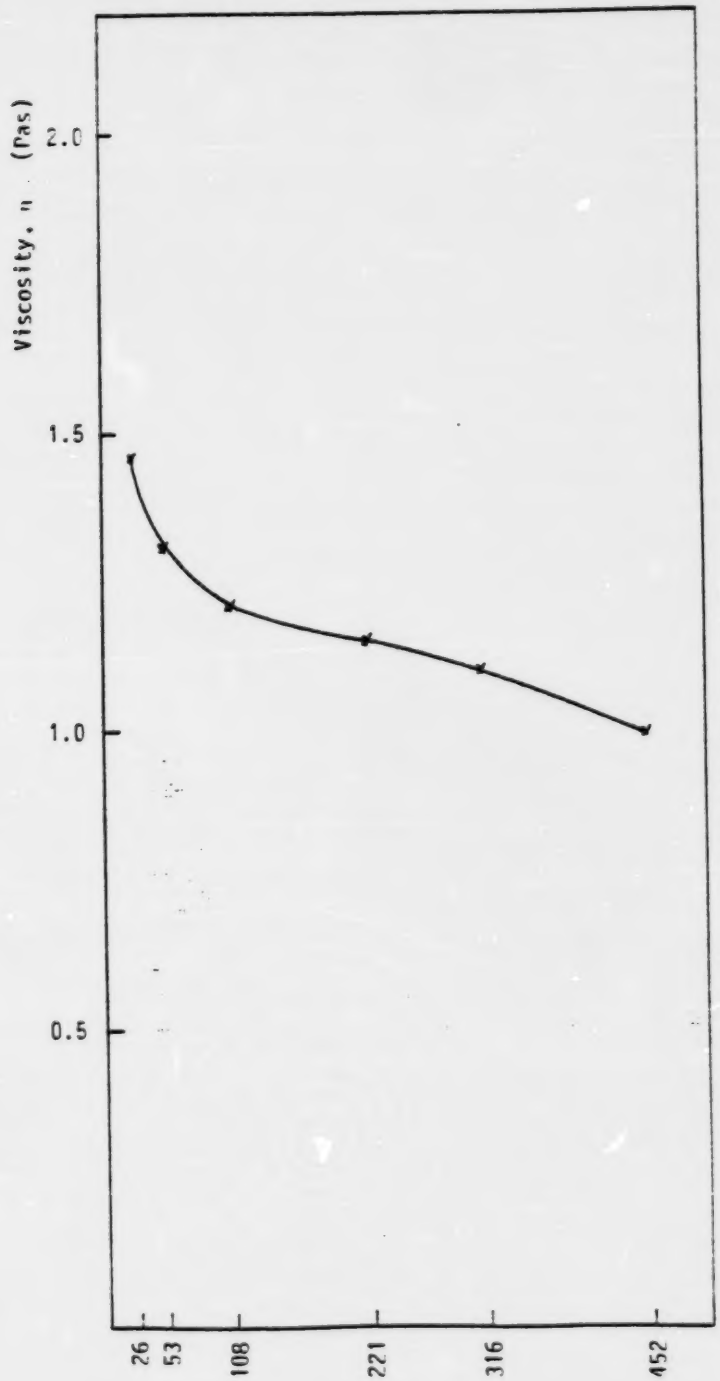
SC: 71.3 %
6g Carbofix B3/kg coal
0.56 g Carbofix C-13/kg co
δ: 1.23 g/cm³

Carbogel

THE INFLUENCE OF THE SHEAR RATE ON THE VISCOSITY

Diagram 2

COAL	DATE	NOTES
Coal creek	850427	Rheology measured after 15 days storage
MEASURING SYSTEM	SIGN	
DIN-125	H. M	



Note:

- -Dispersants
- -Solids content
- -Density
- -Stabilizer
- -Others

SC: 72.3 %

5g Carbofix B3/kg coal

0.69 g Carbofix C-13/kg coal

δ: 1.21 g/cm³

The rheology during the decellerating phas of this sample was not assessed.

Carbogel

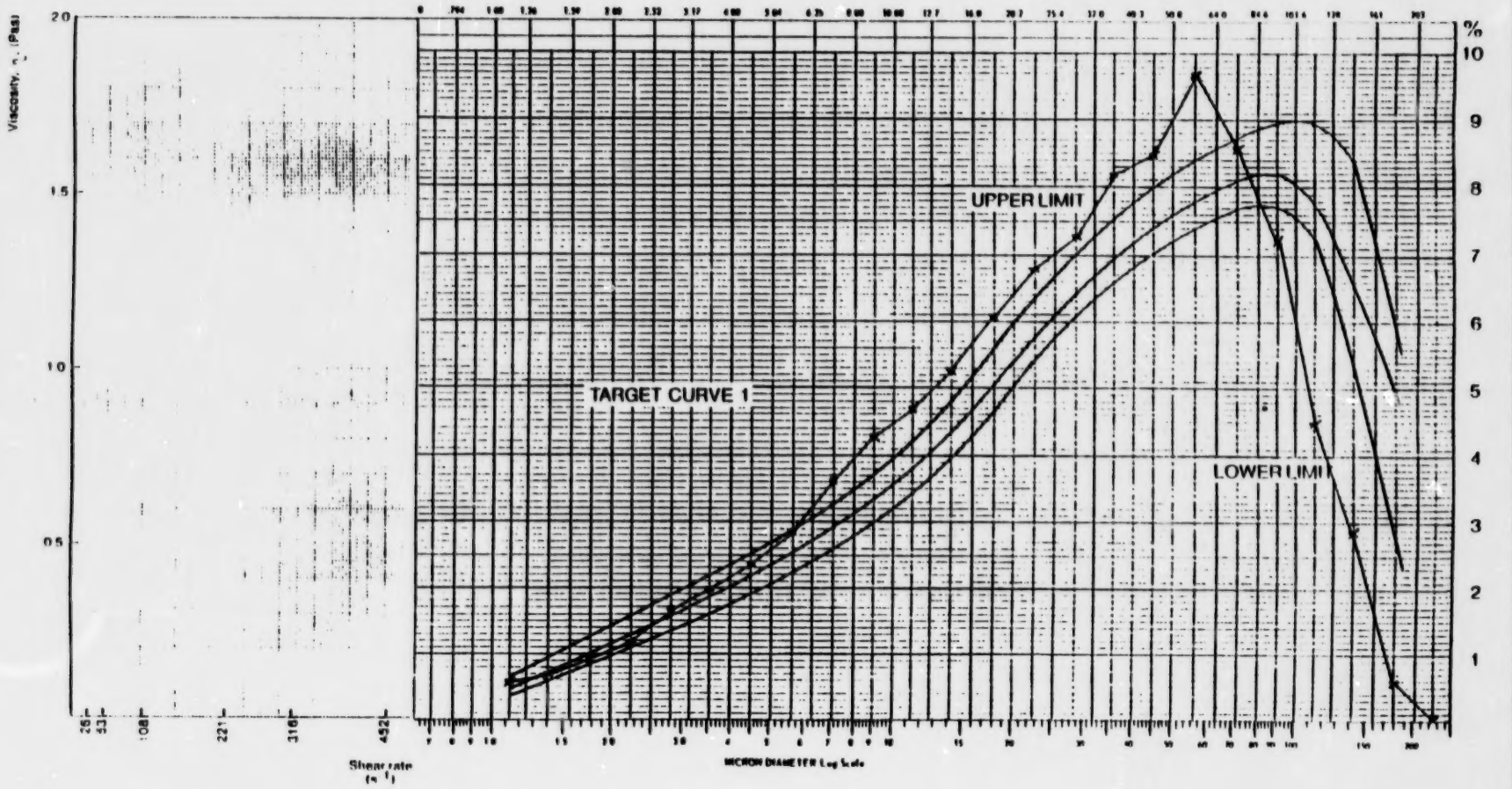
THE PARTICLE SIZE DISTRIBUTION AND THE INFLUENCE OF THE SHEAR RATE ON THE VISCOSITY OF SAMPLES WITH DIFFERENT SOLIDS CONTENTS

COAL	MEASURING SYSTEM	C C C	CORRELATION SIZES
Green Hill			400. 140. 50 µm
ADDITIVE CONC AT HIGHEST S C g/kg coal	DENSITY AT HIGHEST S C g/cm³	ADDITIVE CONC AT C C C g/kg coal	DATE/SIGN 850220 / K.S

GHO-225/226

x 95/5

Diagram 3

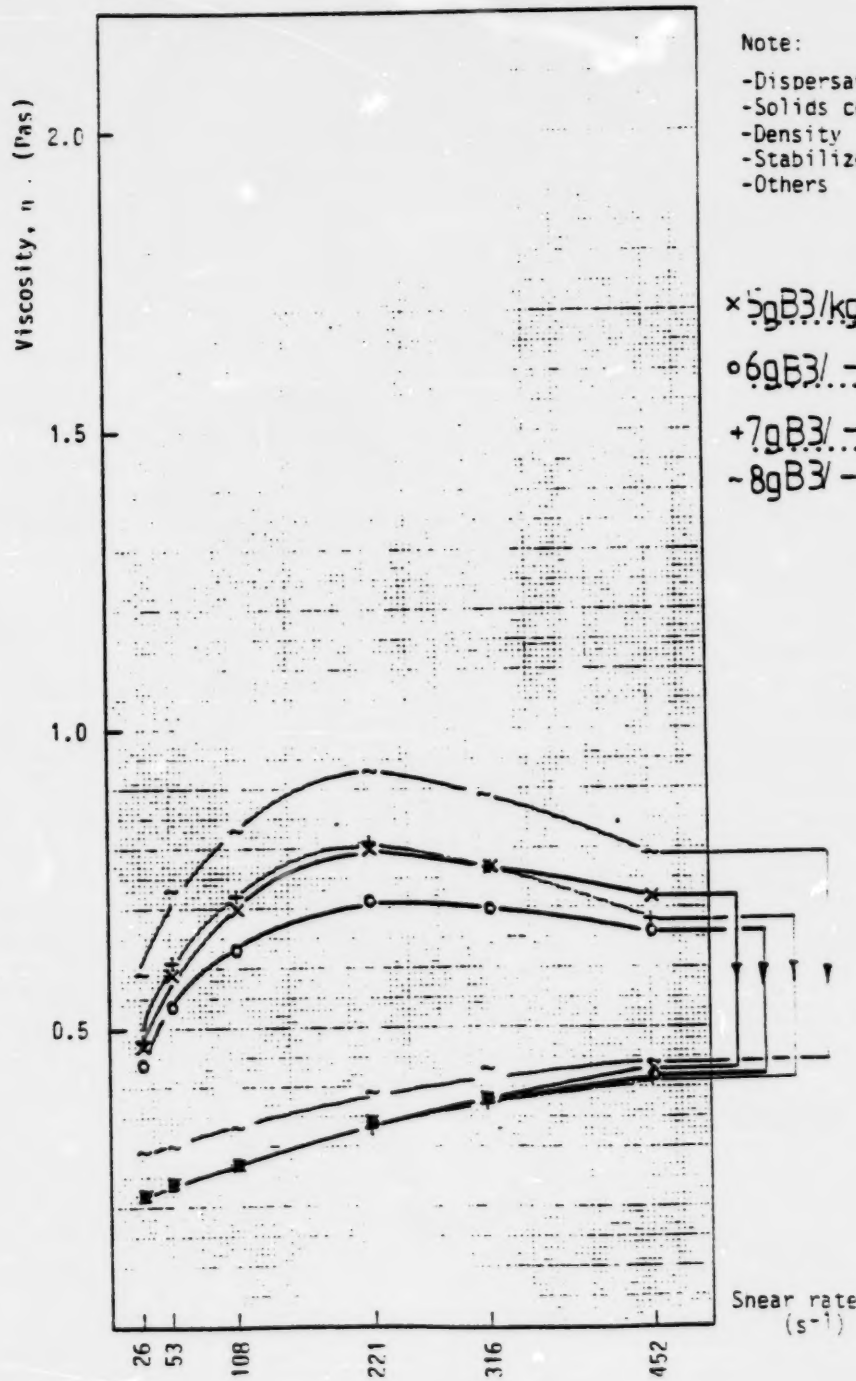


Carbogel

THE INFLUENCE OF THE SHEAR RATE ON THE VISCOSITY

Diagram 4

COAL	DATE	NOTES
95/5 GHO225/226	850220	n-min
MEASURING SYSTEM	SIGN	
125		d: 1.22 g/cm³



Note:

-Dispersants
-Solids content
-Density
-Stabilizer
-Others

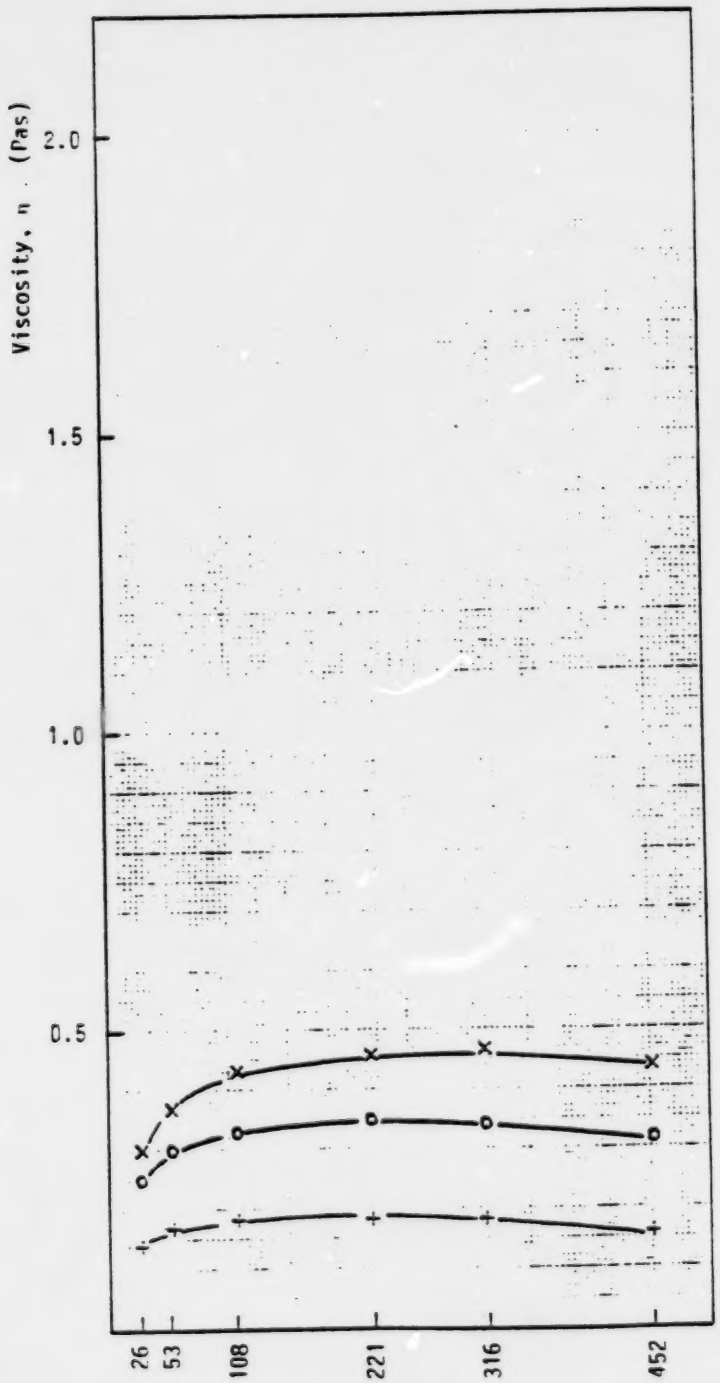
× 5g B3/kg coal SC74
○ 6g B3/ SC74
+ 7g B3/ SC74
~ 8g B3/ SC74

Carbogel

THE INFLUENCE OF THE SHEAR RATE ON THE VISCOSITY

Diagram 5

COA.	DATE	NOTES
95/5GHO 225/226	850220	C.C.C.
MEASURING SYSTEM	SIGN	
125		16gE3/kg coal



Note:

-Dispersants
-Solids content
-Density
-Stabilizer
-Others

×SC:73.0 %...

○SC:71.8 %...

+SC:69.4 %...

Carbogel

THE INFLUENCE OF THE SOLIDS CONTENTS ON THE VISCOSITY

Diagram 6

		DATE
95/5 GHO 225/226	7.7 :	850220
ADDITIVE	MEASURING SYSTEM	SIGN
6 g/kg coal	125	

- o 6g B3/kg coal
- x 7g B3/ -·-·-
- ~ 7g B3/ -·-· 0,5g F1/ kg coal
- + 7g B3/ -·-· 1,5g F1/ -·-·-
- • 7g B3/ -·-· 0,5g F4/ -·-·-
- ^ 7g B3/ -·-· 1,5g F4/ -·-·-

S.C. (%)

65 70 75 80

0.5 1.0 1.5

η at 452 s^{-1}, Acc (Pas)

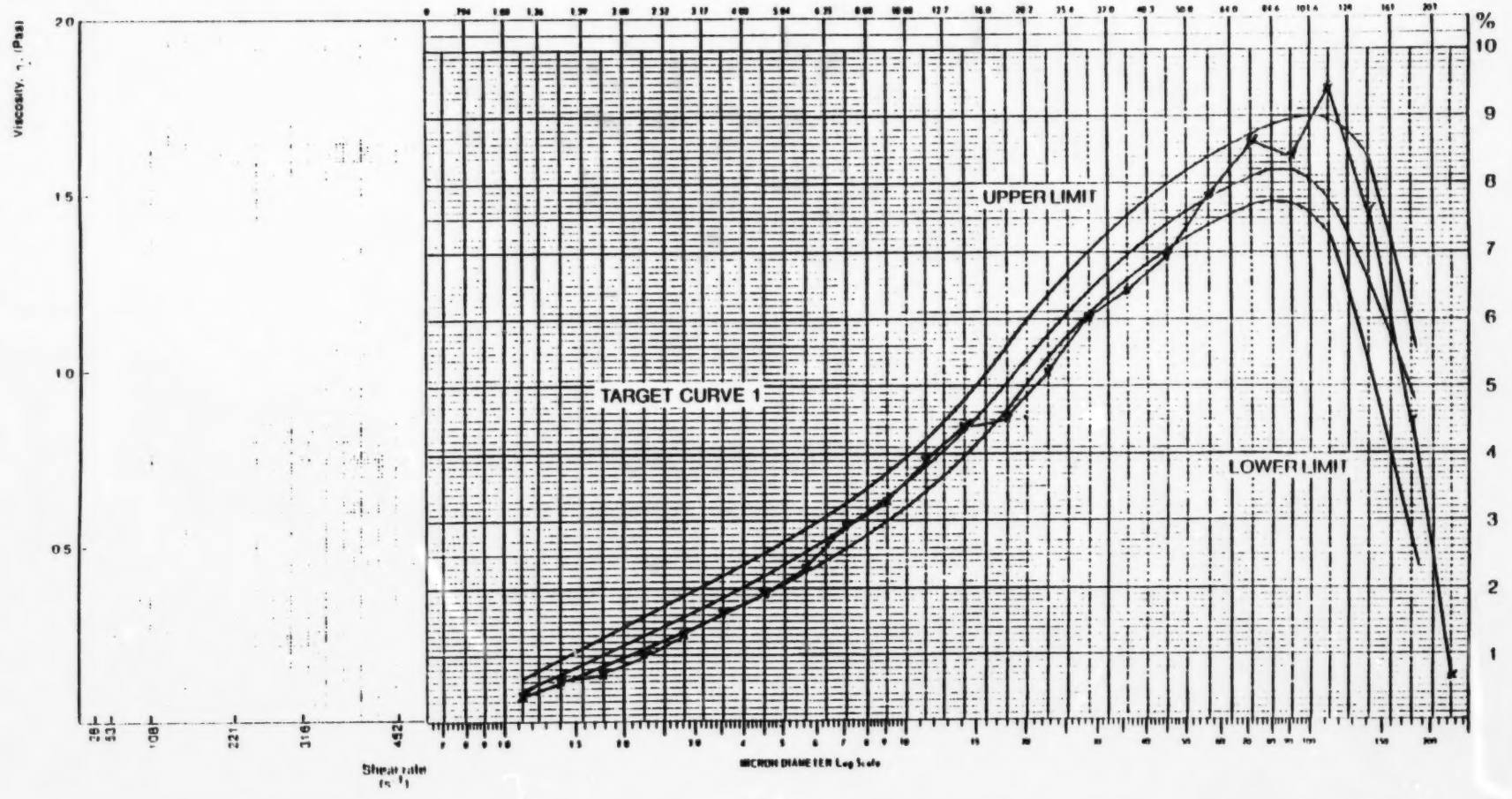
Carbogel

THE PARTICLE SIZE DISTRIBUTION AND THE INFLUENCE OF THE SHEAR RATE ON THE VISCOSITY OF SAMPLES WITH DIFFERENT SOLIDS CONTENTS

× GHO-241

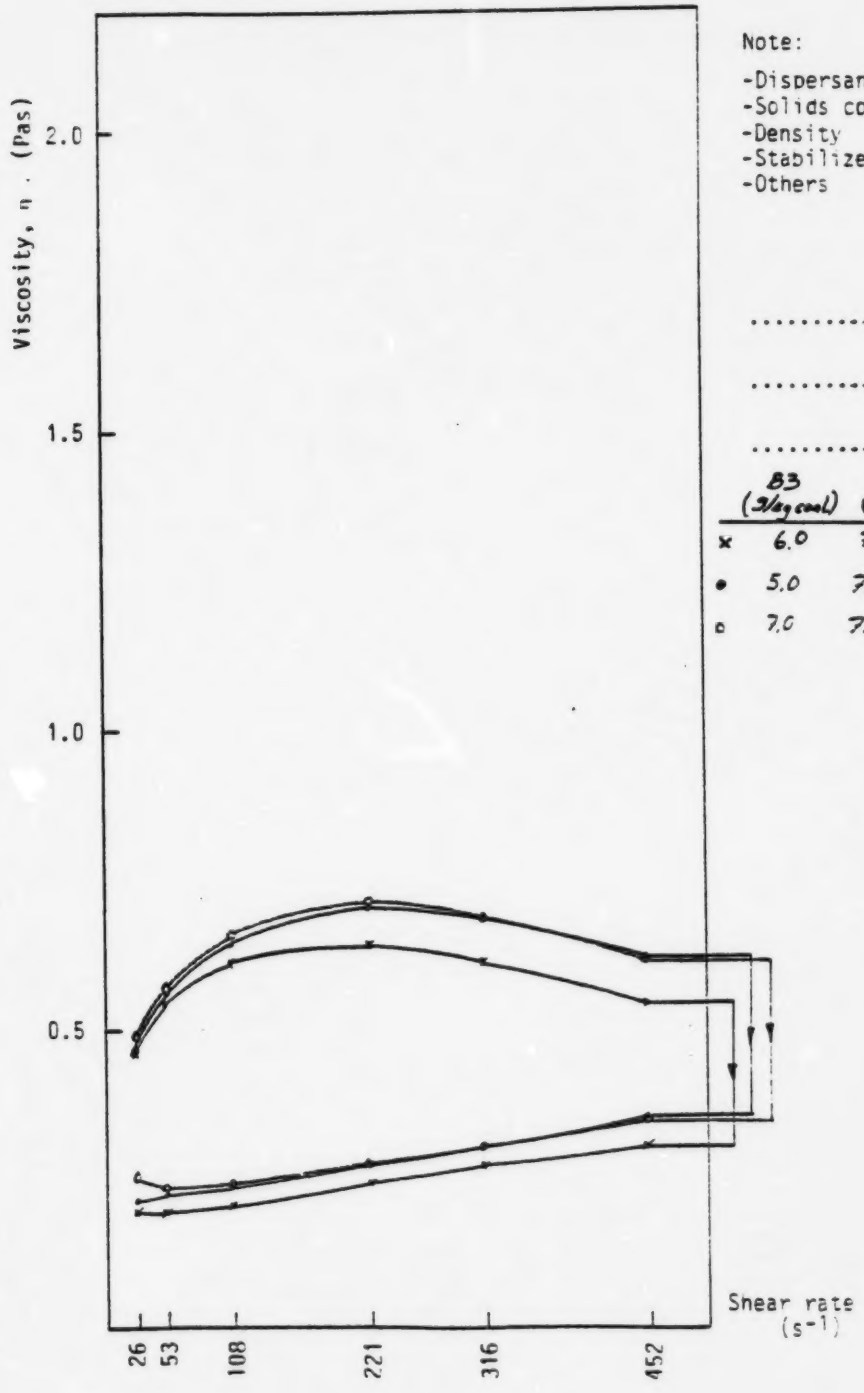
Diagram 7

COAL	MEASURING SYSTEM	C C C	COULTER TUBE SIZES
Green Hill			400. 140. 50 µm
ADDITIVE CONC AT HIGHEST S C g/kg coal	DENSITY AT HIGHEST S C g/cm³	ADDITIVE CONC AT C C C g/kg coal	DATE/SIGN



Carbogel — THE INFLUENCE OF THE SHEAR RATE ON THE VISCOSITY — Diagram 8

COAL	DATE	NOTES
Green Hill GHO 230/23/ 90/10	850306	η-min with Carbofix B3
MEASURING SYSTEM: DIN-125	SIGN: HHH	



Note:
-Dispersants
-Solids content
-Density
-Stabilizer
-Others

.....

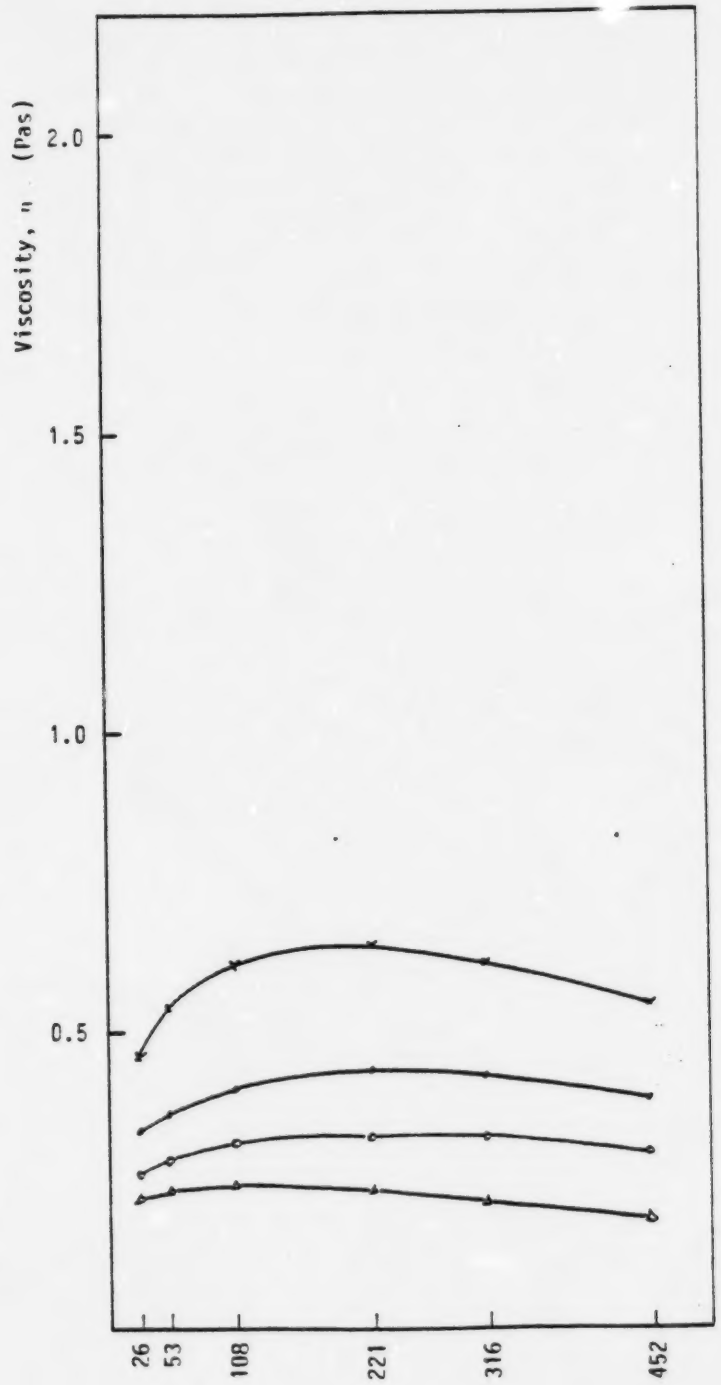
.....

.....

	B3 (g/kg coal)	S.C. (%)	S (g/cm³)
x	6.0	73.3	1.23
•	5.0	73.4	1.23
▫	7.0	73.5	1.23

Carbogel — THE INFLUENCE OF THE SHEAR RATE ON THE VISCOSITY — Diagram 9

COAL	DATE	NOTES
Green Hill GHO 230/231 90/10	850306	C.C.C 6 g Carbofix B3/kg coal
MEASURING SYSTEM: DIN-125	SIGN: HCW	



Note:
-Dispersants
-Solids content
-Density
-Stabilizer
-Others

.....

.....

.....

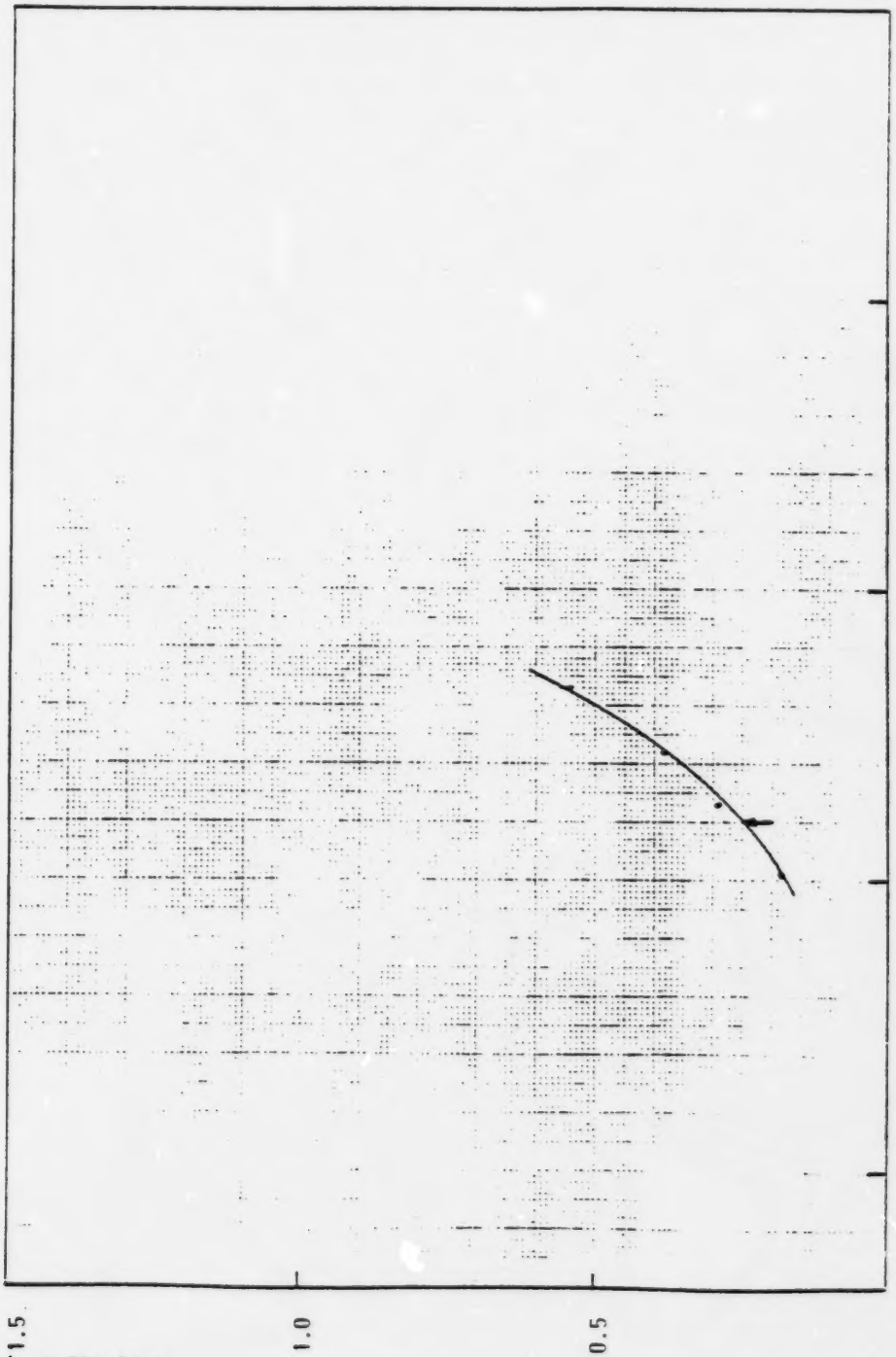
S.C (%)
× 73.3
• 72.2
○ 71.3
△ 70.1

Carbogel

THE INFLUENCE OF THE SOLIDS CONTENTS ON THE VISCOSITY

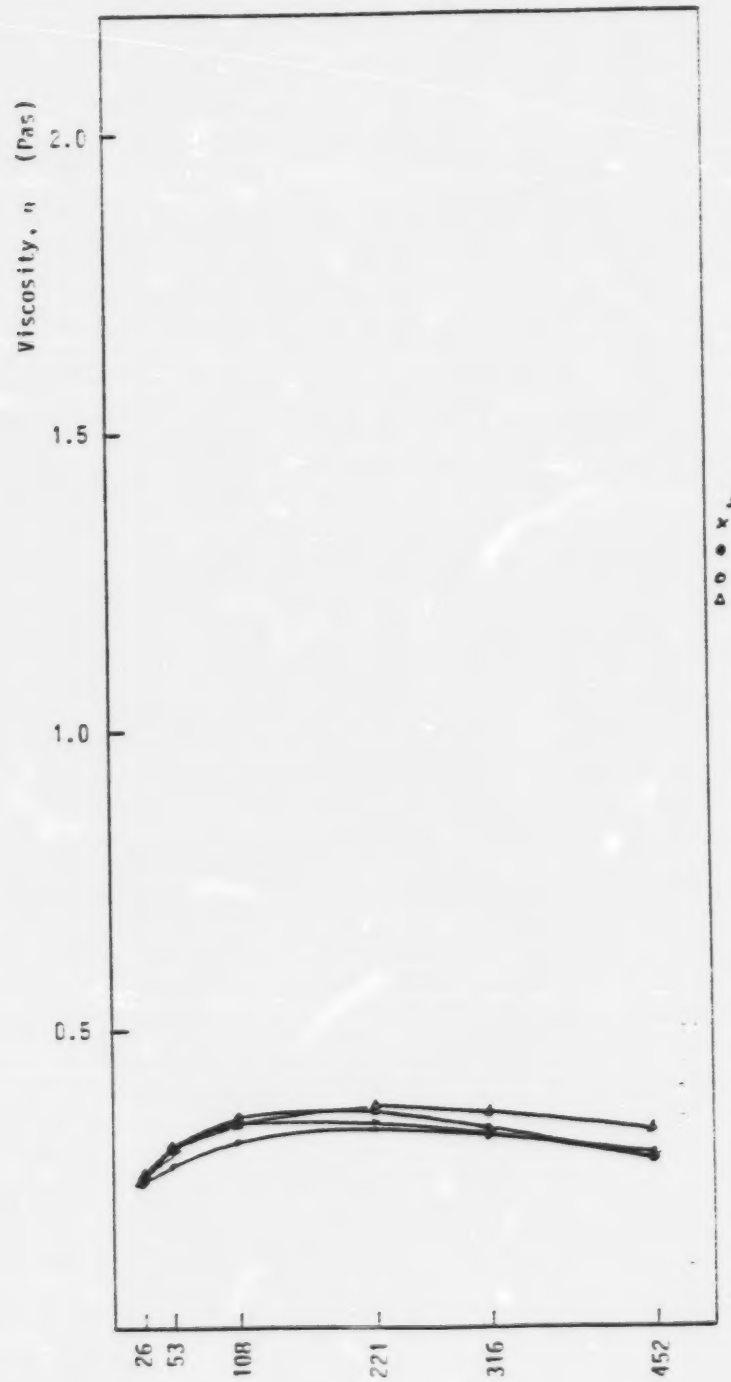
Diagram 10

DA.	C C C	DATE
Green Hill	71.0	850306
ADDITIVE CO. Carbogel B3 6.0 SYKE CO.	MEASURING SYSTEM DIN-125	SIGN H.M



Carbogel — THE INFLUENCE OF THE SHEAR RATE ON THE VISCOSITY — Diagram 11

COAL	DATE	NOTES
Green Hill GHC-830/231 90/10	850307	η-min at ccc
MEASURING SYSTEM	SIGN	
DIN-125	HGHH	



Note:

-Dispersants
-Solids content
-Density
-Stabilizer
-Others

.....

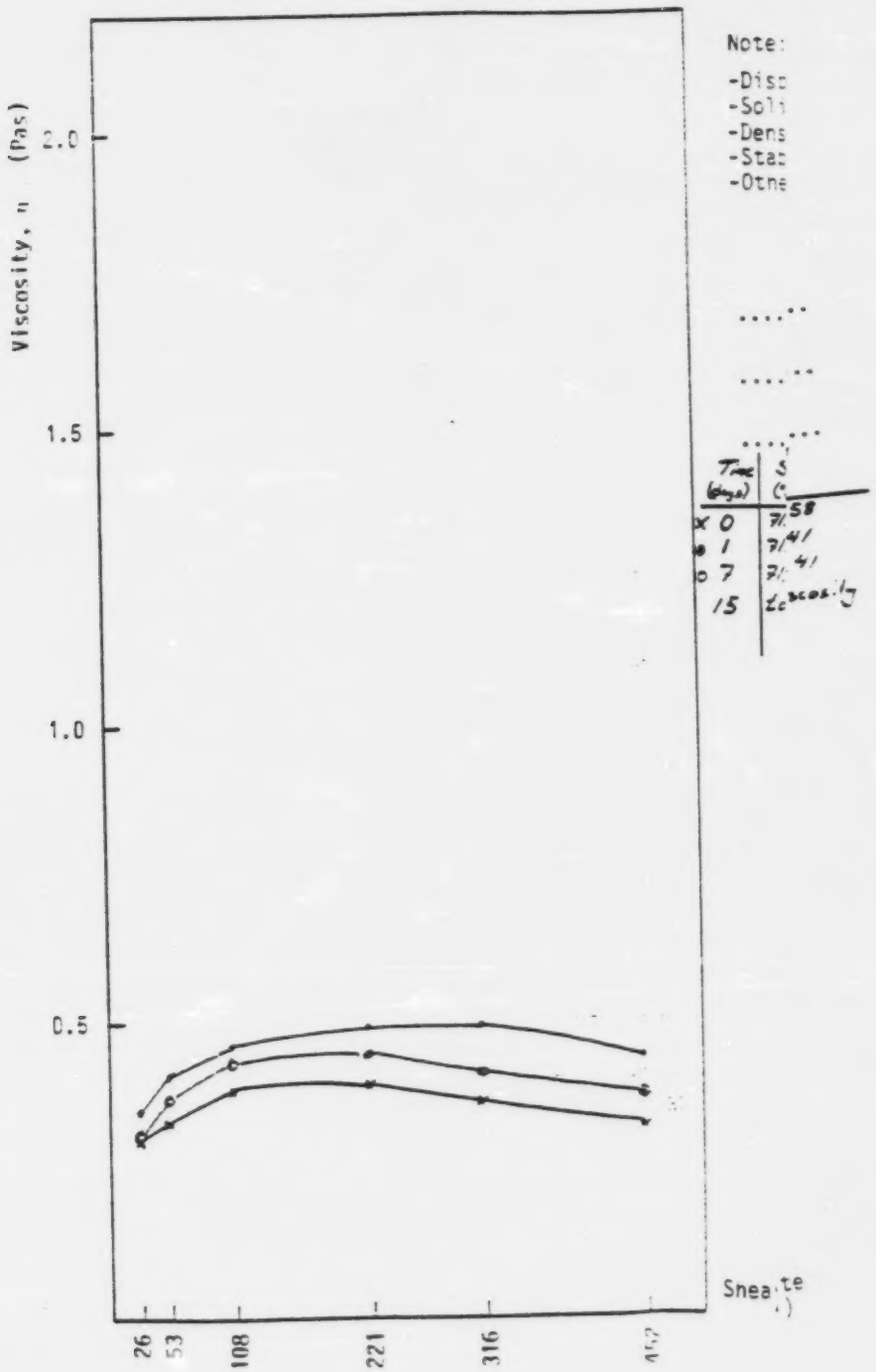
.....

.....

	B3 (l/kg cal)	S.C (%)	δ (g/cm³)
x	4.5	71.2	1.22
•	5.0	71.5	1.22
o	5.5	71.2	1.22
Δ	6.0	71.3	1.22

Carbogel — THE INFLUENCE OF THE SHEAR RATE ON THE VISCOSITY — Diagram 1

COAL	DATE	NOTES
Green Hill	850322	GHD 230/231 90:10
MEASURING SYSTEM	DESIGN	$\eta = f(time)$
DM-125	HM	5.83 l/kg coal

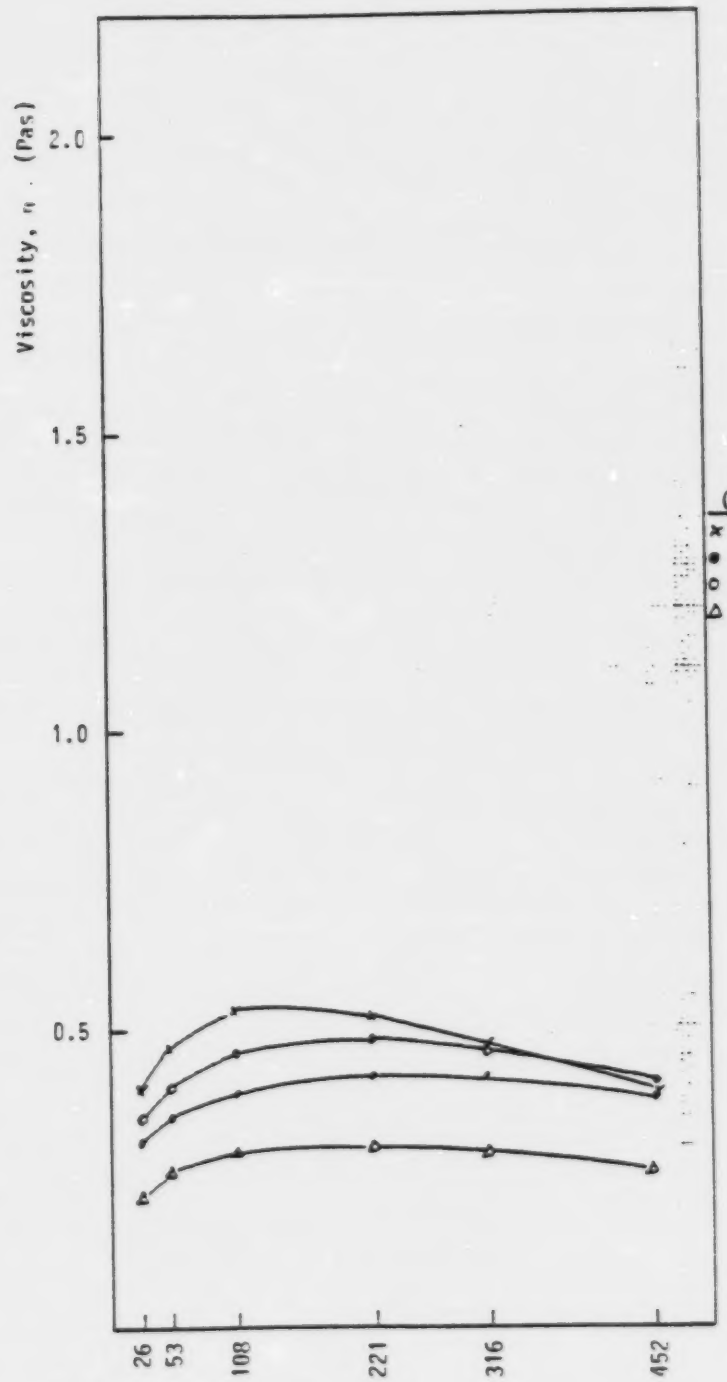


Carbogel

THE INFLUENCE OF THE SHEAR RATE ON THE VISCOSITY

Diagram 13

COAL	DATE	NOTES
Green Hill	850322	GHC 230/231 90:10
MEASURING SYSTEM	SIGN	q - f (time)
DIN - 125	HHK	7g B3/kg coal



Note:

-Dispersants
-Solids content
-Density
-Stabilizer
-Others

.....

.....

.....

	Time (days)	S.C. (%)	δ (g/cm³)	pH
x	0	71.7	1.22	7.60
•	1	71.6	1.23	7.58
o	7	71.8	1.23	7.43
Δ	15	71.8	–	7.51

Carbogel SEDIMENTATION PROPERTIES Diagram 14

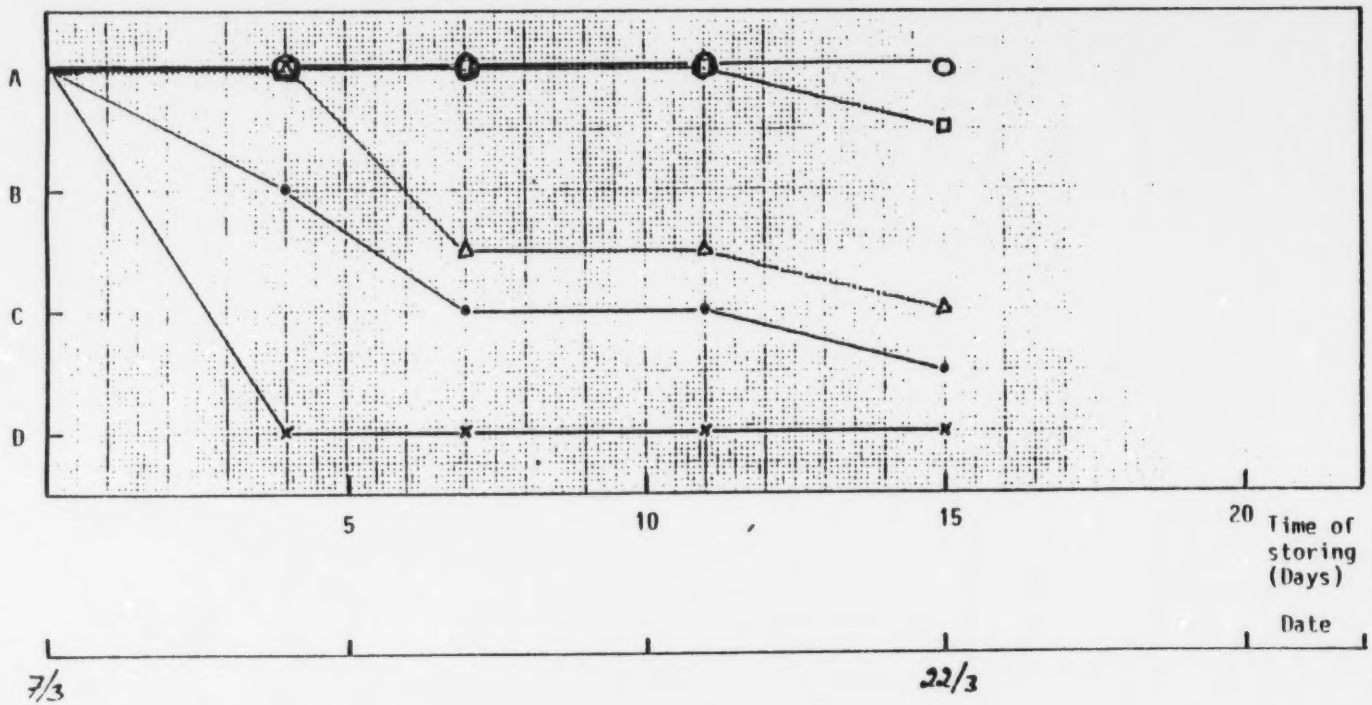
COAL	STABILIZER	DATE/SIGN
Green Hill 6NC-230/231	Carbofix C-13	850308/H.M
ADDITIVE CONC. Carbofix 83 6.0 g/kg coal	NOTE:	TEMP.

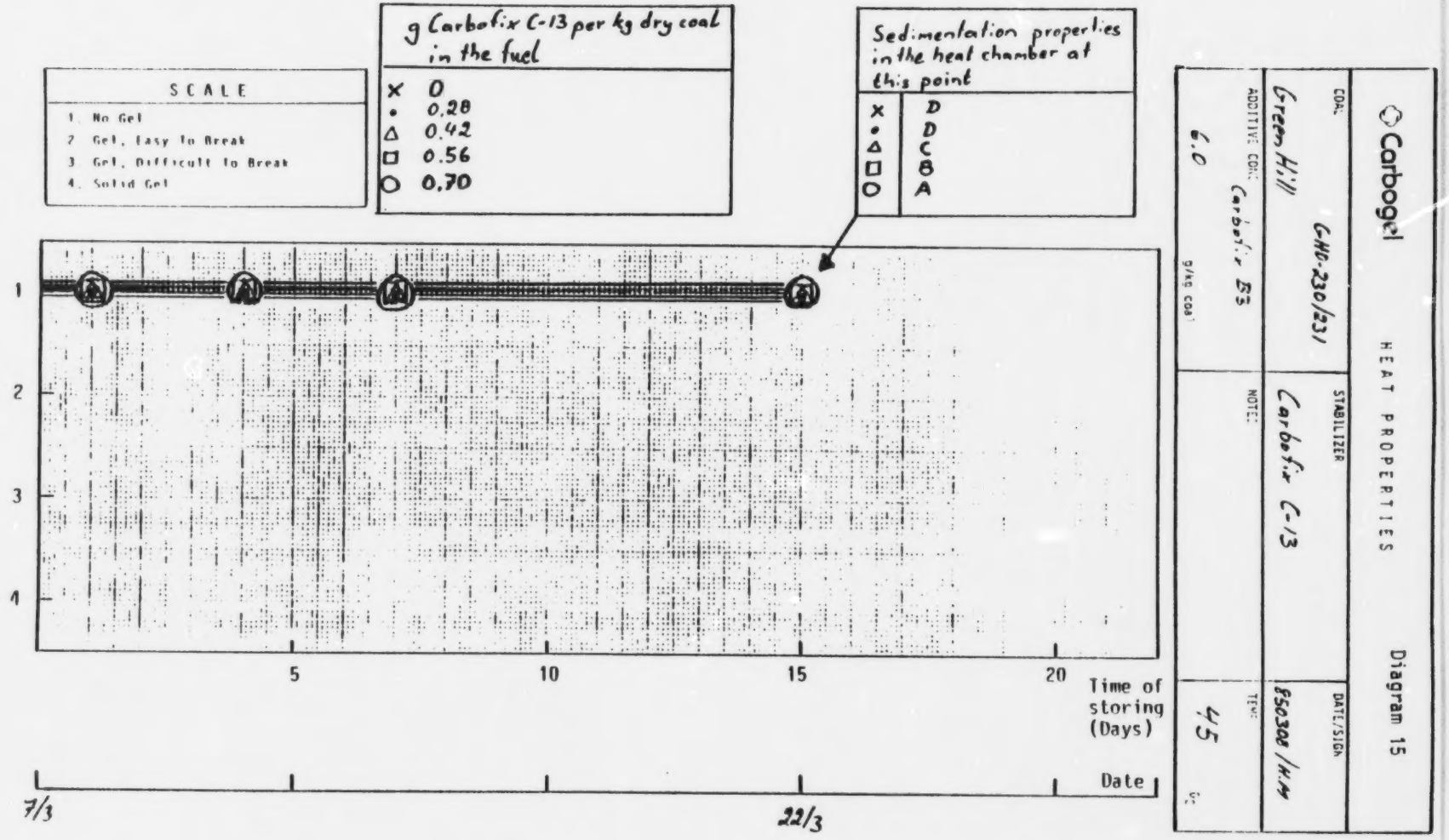
SCALE

A. No Sedimentation
B. Sedimentation tendency (Gradient)
C. Soft Sediment
D. Hard Packed Sediment

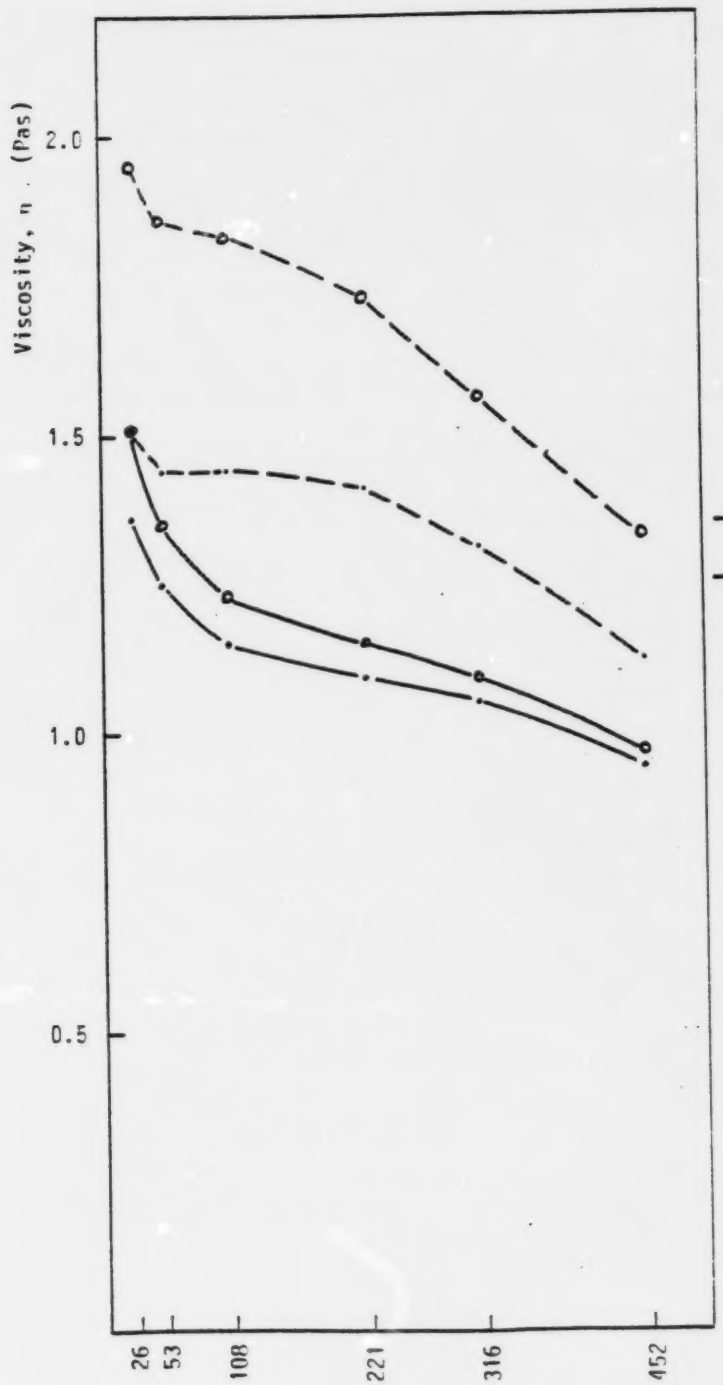
g Carbofix C-13 per kg dry coal in the fuel

× 0
● 0,28
△ 0.42
□ 0.56
○ 0,70




SCALE
1. No Gel
2. Gel, Easy to Break
3. Gel, Difficult to Break
4. Solid Gel
g Carbofix C-13 per kg dry coal in the fuel
× 0
• 0,28
△ 0.42
□ 0.56
○ 0,70
Sedimentation properties in the heat chamber at this point
× • △ □ ○
D D C B A
1
2
3
4
5
10
15
20
Time of storing (Days)
Date
7/3
22/3
Carbogel
HEAT PROPERTIES
Diagram 15
COAL: GHC-230/231
Green Hill
ADDITIVE CONC: Carbofix ES
6.0
g/kg coal
STABILIZER
Carbofix C-13
NOTE:
DATE/SIGN
150388/HM
TEMP
45
°C

Carbogel	The Influence Of The Shear Rate On The Viscosity	Diagram 16
COAL: Green Hill	DATE: 850322	NOTES: Stabilized fuels measured at two different points of time
MEASURING SYSTEM: DIN-125	SIGN: H. M.	



Note:
-Dispersants
-Solids content
-Density
-Stabilizer
-Others

SC ~ 71.3 %

6 g Carbofix B3/kg coa

1 day after prepara

14 days after preparati

○ 0.70 g Carbofix C-1
per kg coal

● 0.56 g Carbofix C-1
per kg coal

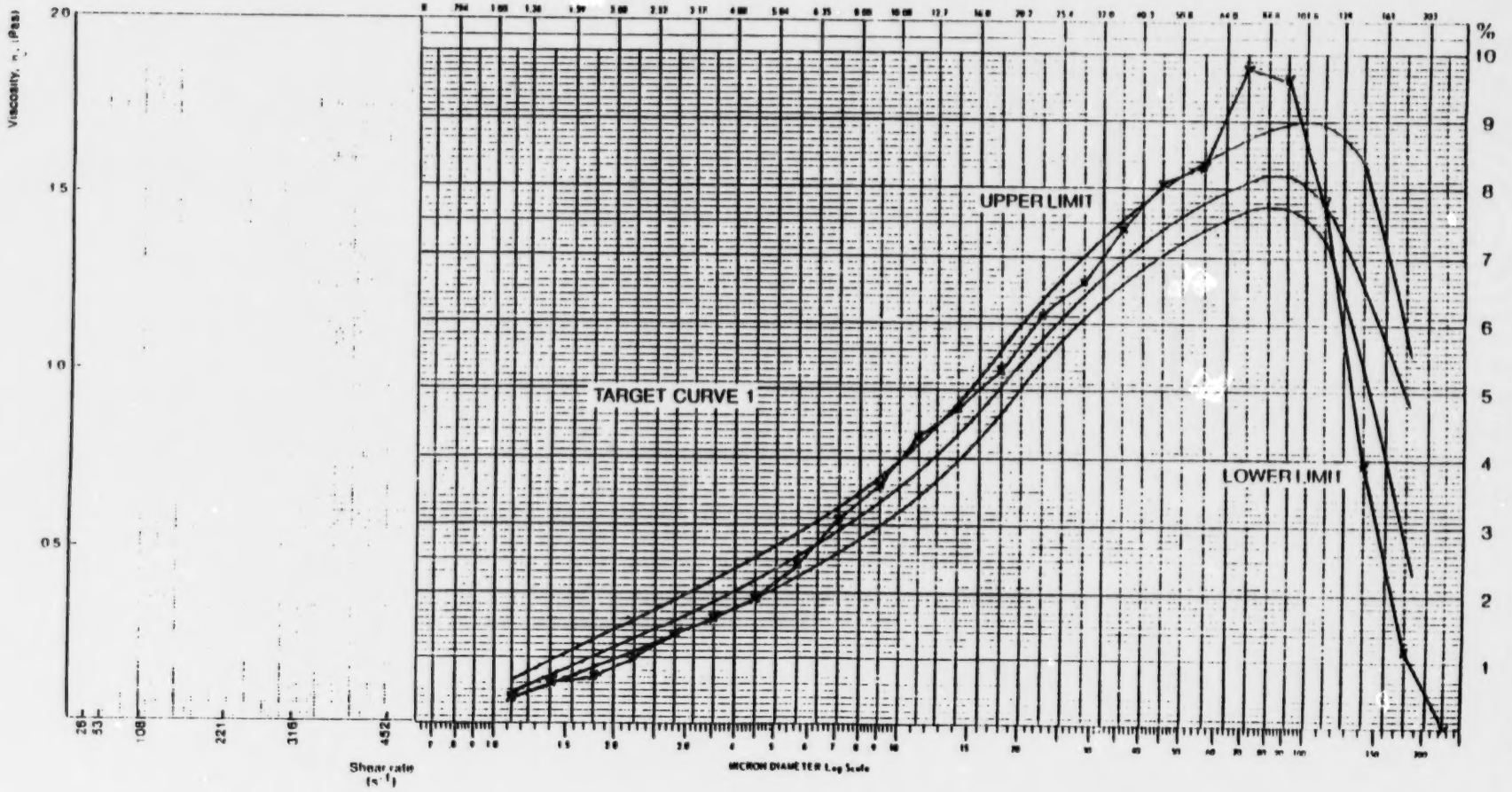
Carbogel

THE PARTICLE SIZE DISTRIBUTION AND THE INFLUENCE OF THE SHEAR RATE ON THE VISCOSITY OF SAMPLES WITH DIFFERENT SOLIDS CONTENTS

CCO-229

Diagram 17

COAL	MEASURING SYSTEM	C C C	COULTER TUBE SIZES
Coal Creek			400, 140, 50 µm
ADDITIVE CONC AT HIGHEST S C g/kg coal	DENSITY AT HIGHEST S C g/cm³	ADDITIVE CONC AT C C C g/kg coal	DATE/SIGN 850225 / H.M

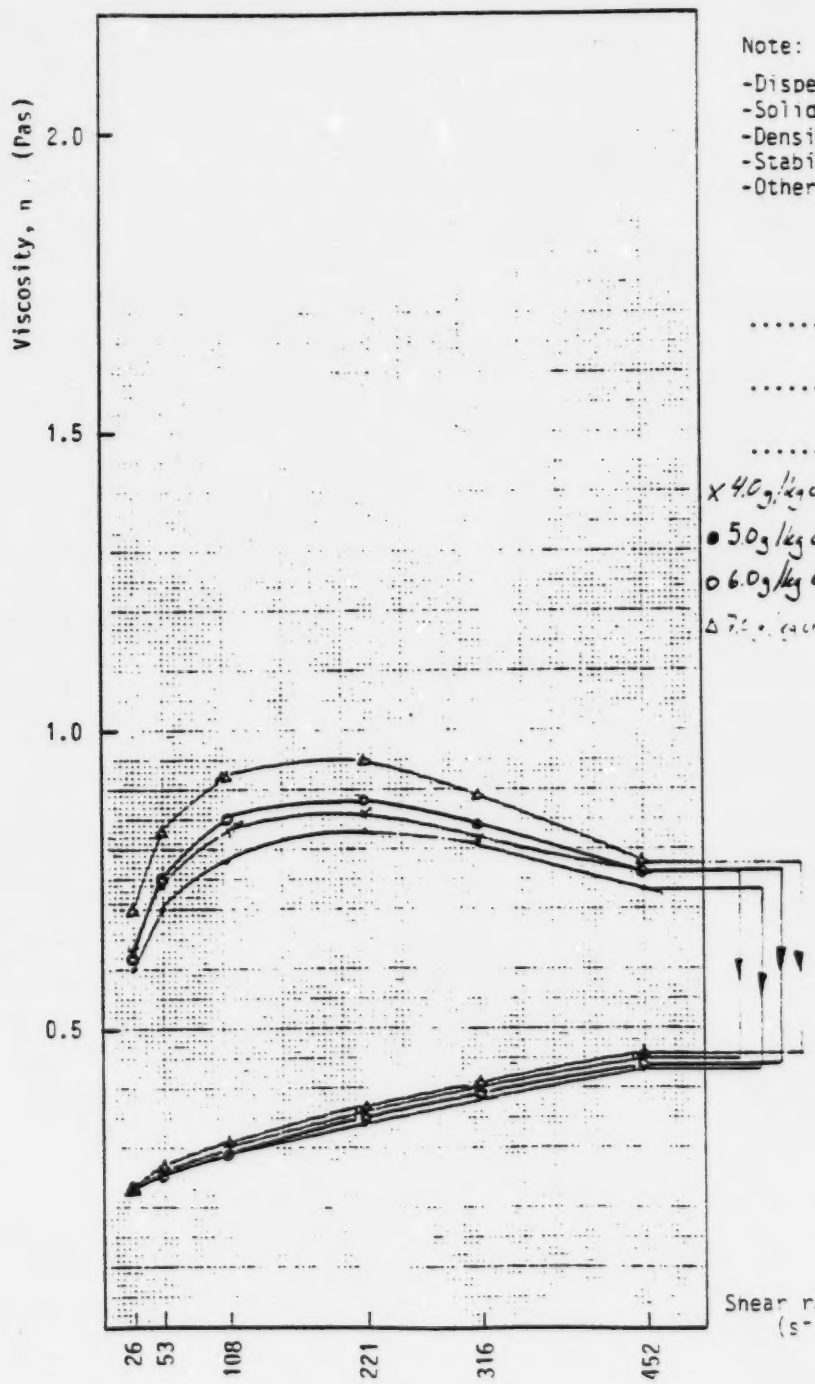


Carbogel

THE INFLUENCE OF THE SHEAR RATE ON THE VISCOSITY

Diagram 18

COAL	DATE	NOTES
Coal creek	850225	η-min. with Carbofix B5
MEASURING SYSTEM	SIGN	
DIN-125	[illegible]	



Note:

-Dispersants
-Solids content
-Density
-Stabilizer
-Others

.....

.....

.....

	S.C(%)	Stab.
× 4.0 g/kg coal	75.2	1.23
• 5.0 g/kg coal	74.9	1.22
○ 6.0 g/kg coal	75.2	1.22
△ 7.0 g/kg coal	75.2	1.22

Carbogel

THE INFLUENCE OF THE SOLIDS CONTENTS ON THE VISCOSITY

Diagram 19

COAL	S.C.	DATE
Coal creek	71.9	850222
ADDITIVE CONC. 5.0 Carbofix B3 g/kg coal	MEASURING SYSTEM DIN - 125	SIGN

CCO-242/243

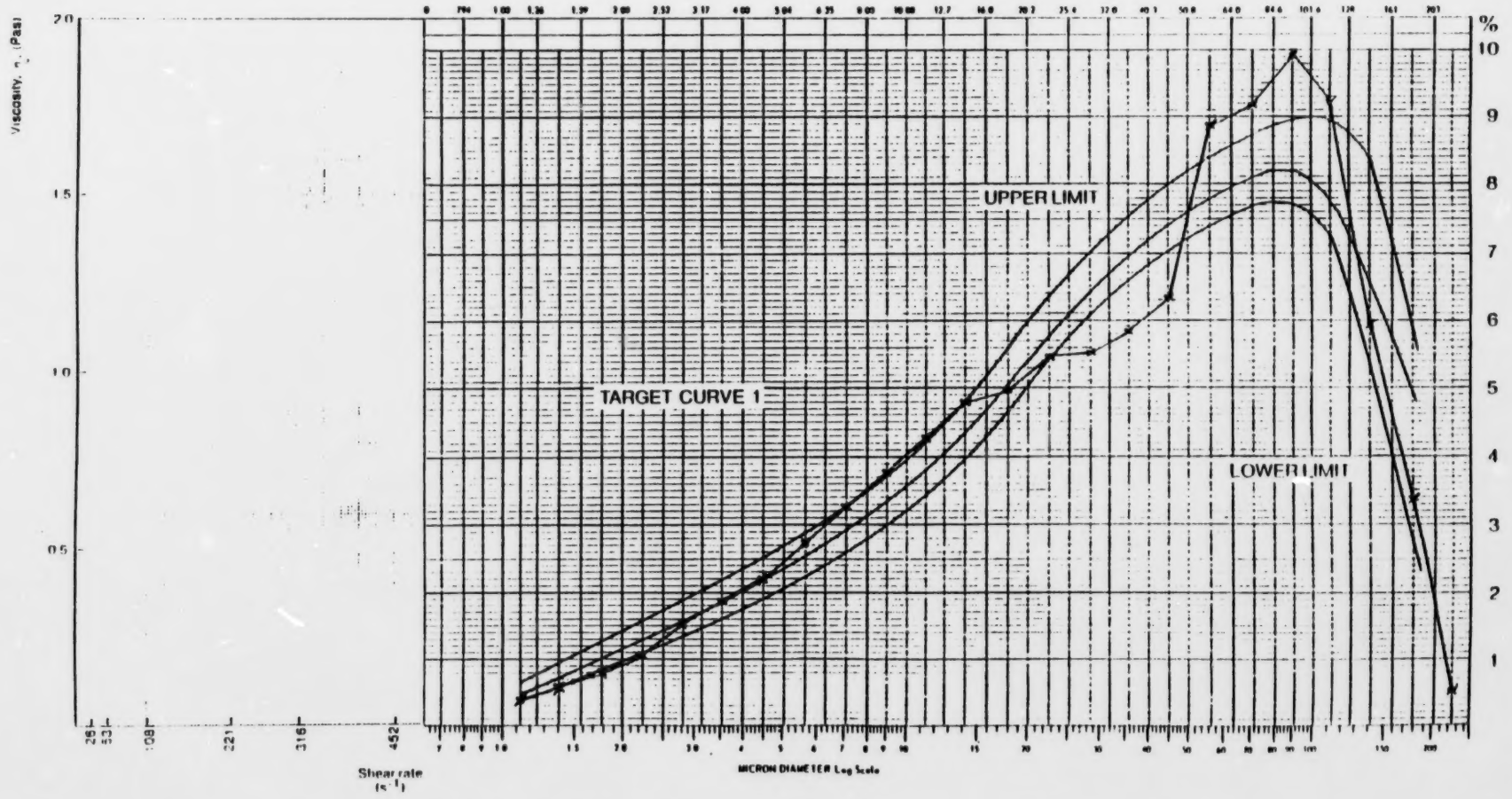
× 80/20

Carbogel

THE PARTICLE SIZE DISTRIBUTION AND THE INFLUENCE OF THE SHEAR RATE ON THE VISCOSITY OF SAMPLES WITH DIFFERENT SOLIDS CONTENTS

COAL	MEASURING SYSTEM	C C C	COULTER HURF SIZES
Coal Creek			400, 140, 50 µm
ADDITIVE CONC AT HIGHEST S C	DENSITY AT HIGHEST S C	ADDITIVE CONC AT C C C	DATE/SIGN
g/kg coal	g/cm³	g/kg coal	

Diagram 20

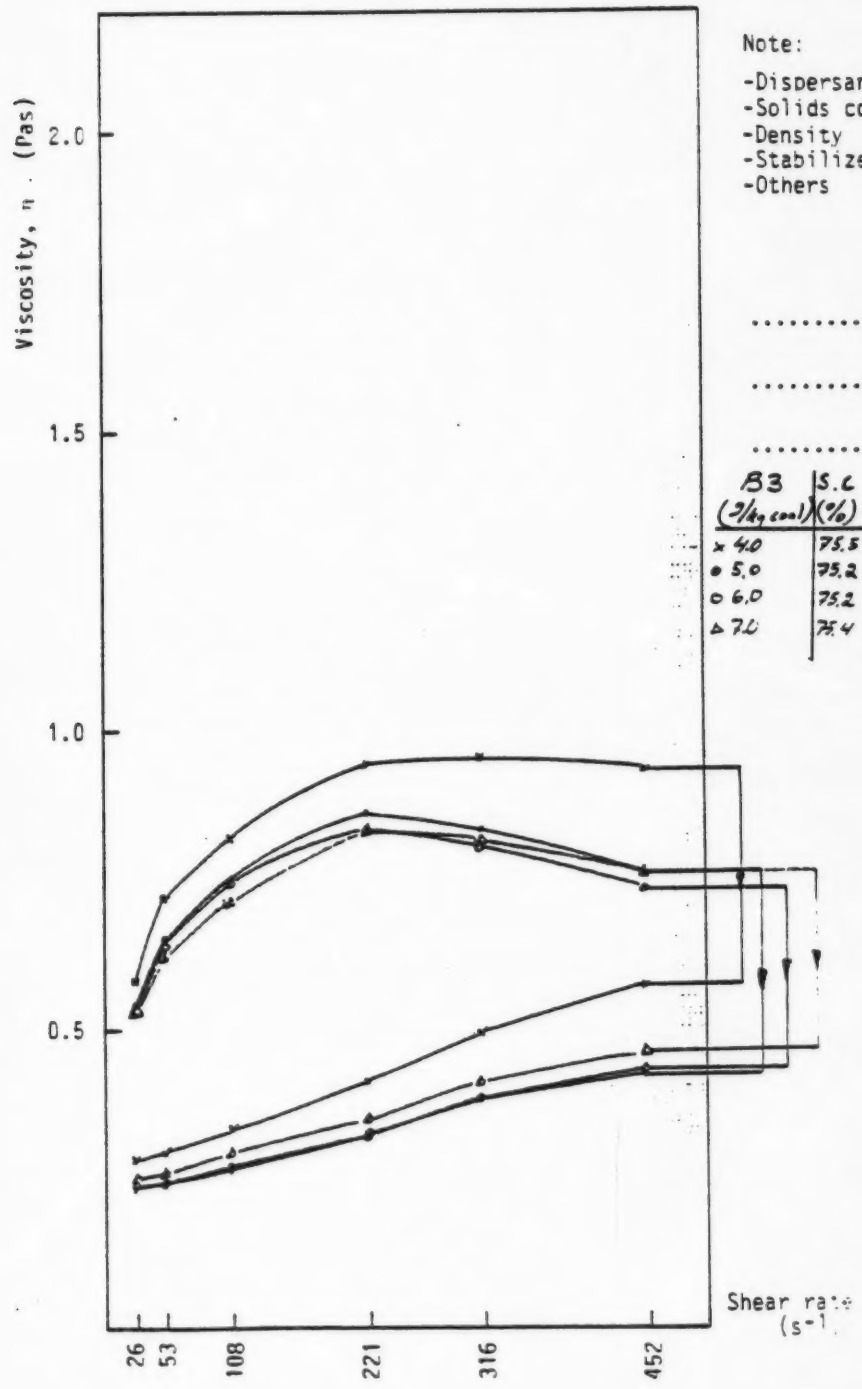


Carbogel

THE INFLUENCE OF THE SHEAR RATE ON THE VISCOSITY

Diagram 21

COAL	DATE	NOTES
Coal creek	850313	CCO-242/243 80:20
MEASURING SYSTEM	SIGN	η-min with Carbofix B3
DIN-125	HAM	



Note:

-Dispersants
-Solids content
-Density
-Stabilizer
-Others

.....

.....

.....

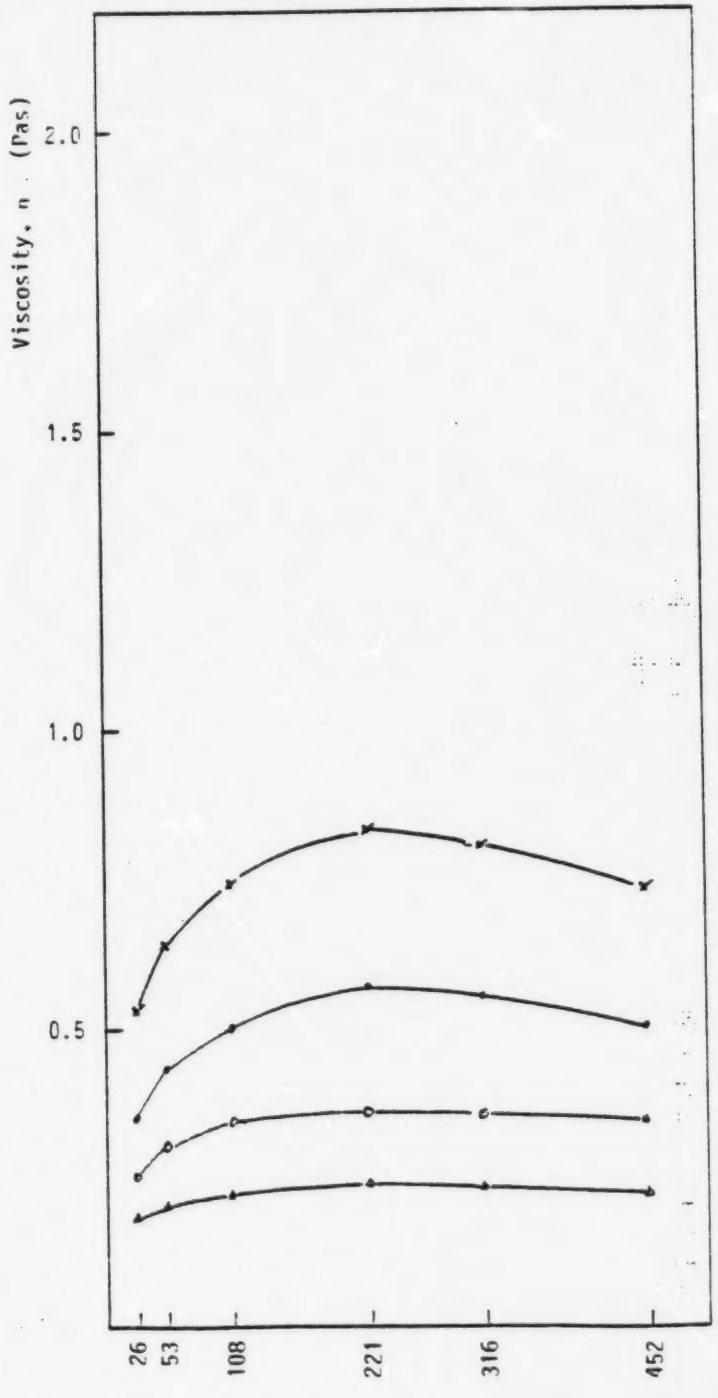
B3 (g/kg coal)	S.C (%)	S (g/cm³)
× 4.0	75.5	1.22
• 5.0	75.2	1.22
○ 6.0	75.2	1.22
△ 7.0	75.4	1.22

Carbogel

THE INFLUENCE OF THE SHEAR RATE ON THE VISCOSITY

Diagram 22

COAL	DATE	NOTE!
Coal creek	850313	CCO-242/243 80:20 6.0 g Carbofix B3/kg coal CCC
MEASURING SYSTEM	SIGN	
DIN-125	[signature]	



Note:

-Dispersants
-Solids content
-Density
-Stabilizer
-Others

.....

.....

.....

S.C.

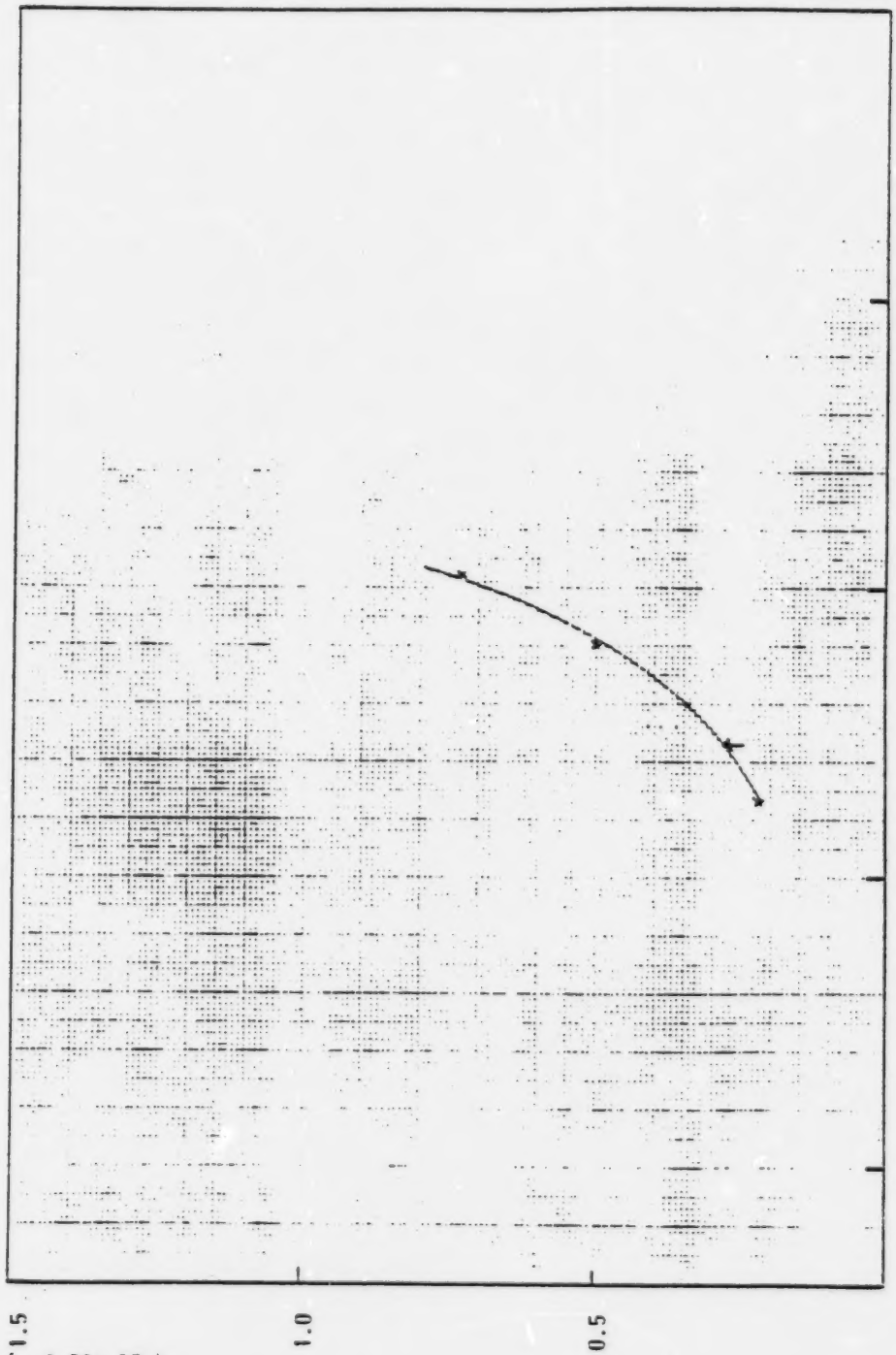
× 75.2 %
• 74.0 %
○ 73.0 %
△ 71.3 %

Carbogel

THE INFLUENCE OF THE SOLIDS CONTENTS ON THE VISCOSITY

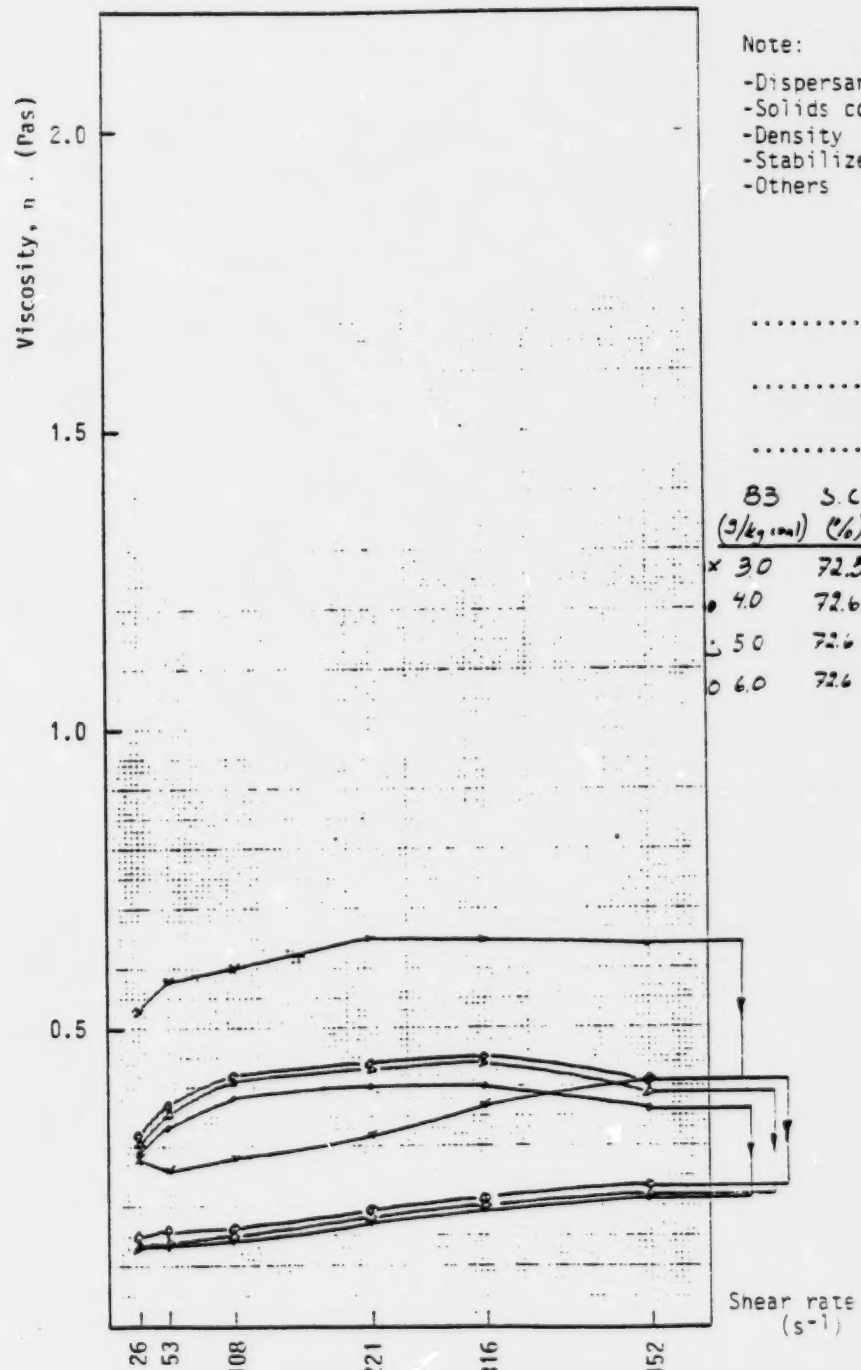
Diagram 23

COAL	C C C	DATE
Coal creek CCC-243, 243	72.3	5/03/2
ADDITIVE CONC. Carbofix B3 0.1 % BY KG COAL	MEASURING SYSTEM DIN-135	SIGN



Carbogel — THE INFLUENCE OF THE SHEAR RATE ON THE VISCOSITY — Diagram 24

COAL	DATE	NOTES
Coalcreek	850313	CCO-242/243 80:20
MEASURING SYSTEM	SIGN	η-min at ccc
DIN-125	HCW	

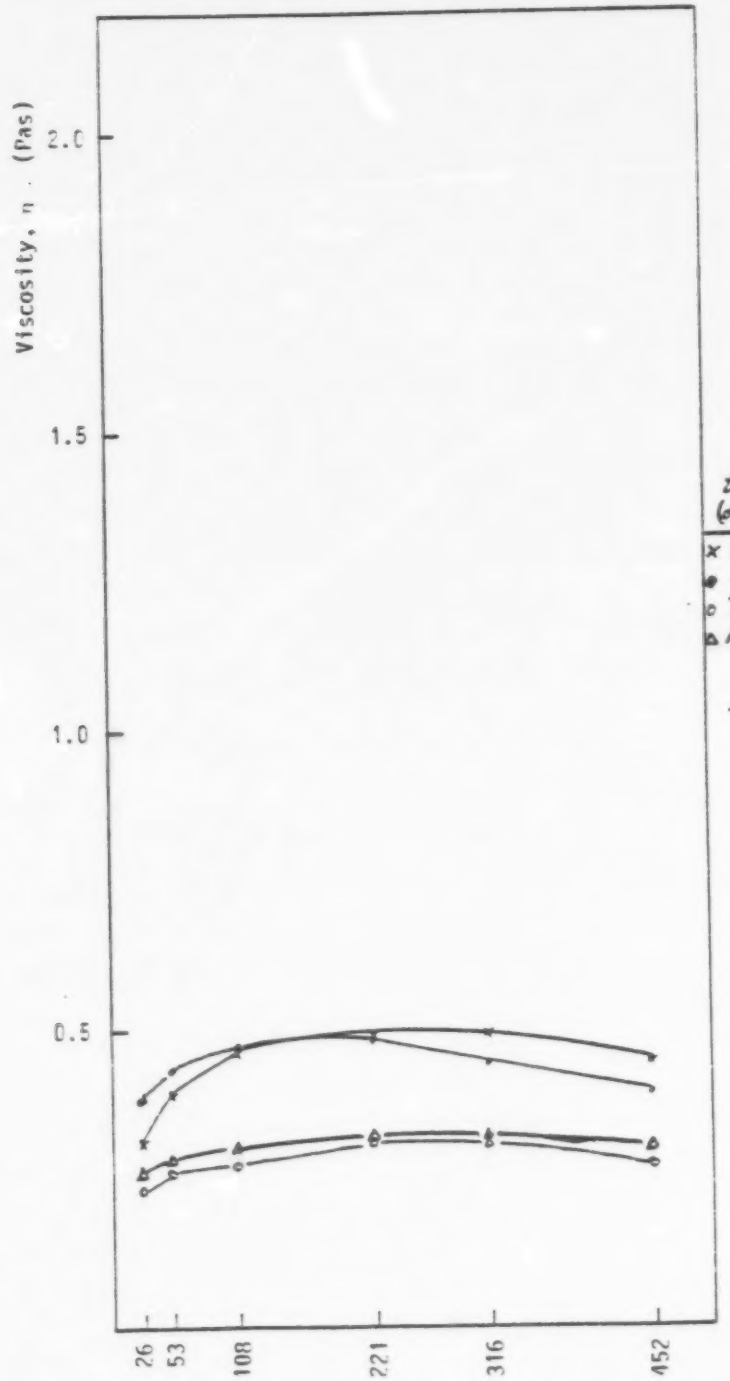


Note:
- Dispersants
- Solids content
- Density
- Stabilizer
- Others

	B3 (g/kg sol)	S.C (%)	δ (g/cm³)
×	3.0	72.5	1.20
•	4.0	72.6	1.21
◡	5.0	72.6	1.21
○	6.0	72.6	1.21

Carbogel — THE INFLUENCE OF THE SHEAR RATE ON THE VISCOSITY — Diagram 25

COAL	DATE	NOTES
Coal creek	850328	CCO-242/243 80/20
MEASURING SYSTEM	SIGN	$\eta = f(time)$
DIN-125		



Note:
- Dispersants
- Solids content
- Density
- Stabilizer
- Others

6g B3/kg coal

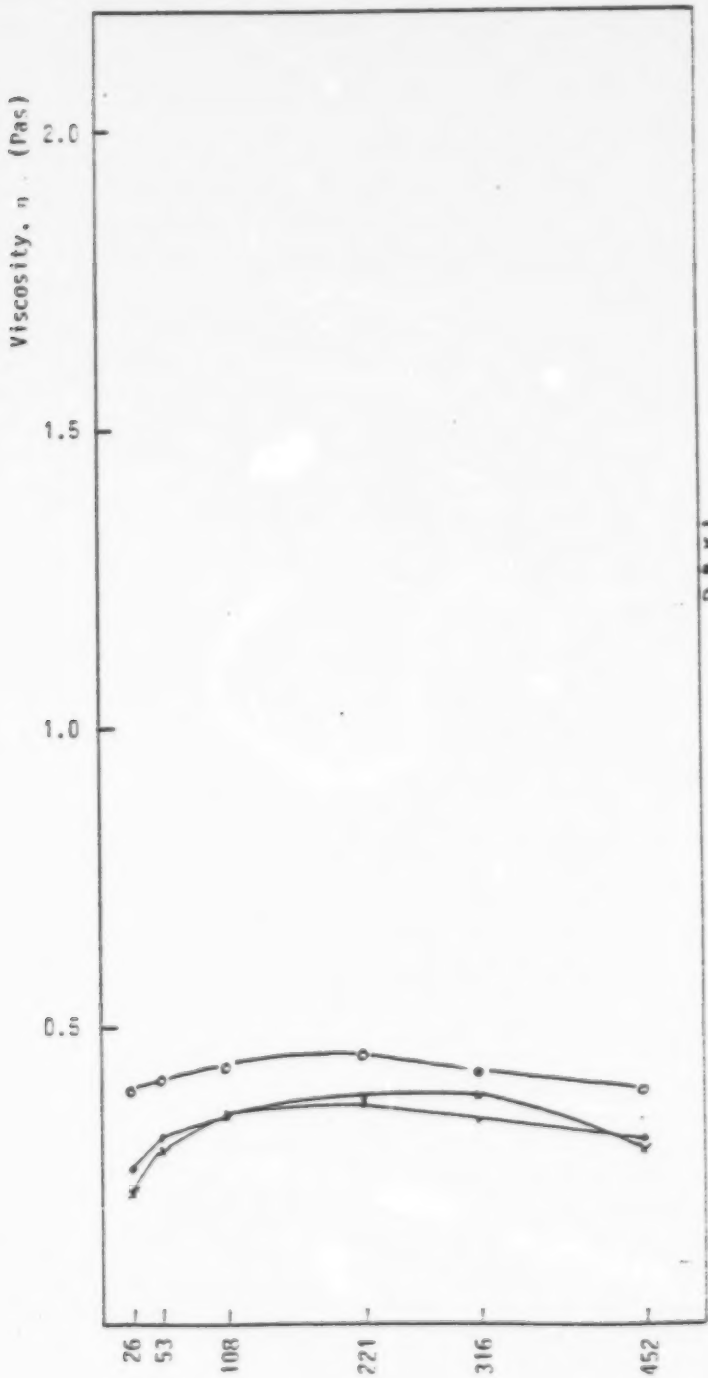
Time (days)	S.C (%)	δ (g/cm³)	pH
× 0	72.4	1.22	8.07
• 1	72.6	1.22	7.91
○ 7	72.5	1.22	7.83
△ 14	72.9	—	7.80

Carbogel

THE INFLUENCE OF THE SHEAR RATE ON THE VISCOSITY

Diagram 26

COAL	DATE	NOTES
Coal creek	850328	CCC-242/243 80/20
MEASURING SYSTEM	SIGN	$\eta = f(time)$
DIN-125		



Note:

-Dispersants
-Solids content
-Density
-Stabilizer
-Others

4g B3/kg coal

time (days)	S.C. (%)	δ (g/cm³)	pH
x 0	72.6	1.22	7.92
• 1	72.4	1.22	7.94
c 7	72.3	1.22	7.94
14	too high viscosity		

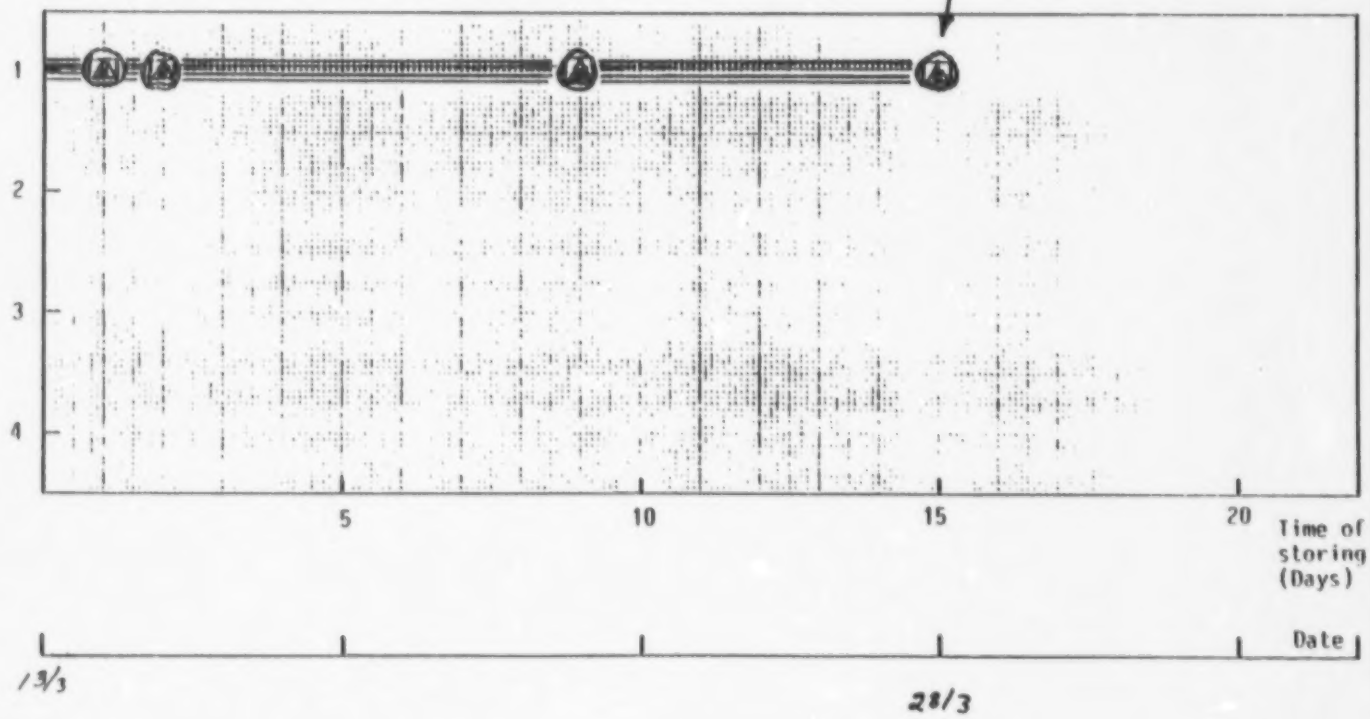
Carbogel — HEAT PROPERTIES — Diagram 27

COAL	STABILIZER	DATE/SIGN
Coal Creek CCO-242/BW3	Carbofix C-13	850313 /N.M
ADDITIVE CONC. Carbofix 83 5.0 g/kg coal	NOTES	TEMP. 45 °C

SCALE
1. No Gel
2. Gel, Easy To Break
3. Gel, Difficult To Break
4. Solid Gel

g Carbofix C-13 per kg dry coal in the fuel	
×	0
•	0.41
△	0.55
□	0.69
○	0.83

Sedimentation properties in the heat chamber at this point	
×	D
•△	C
□	A
○	A



Carbogel SEDIMENTATION PROPERTIES Diagram 28

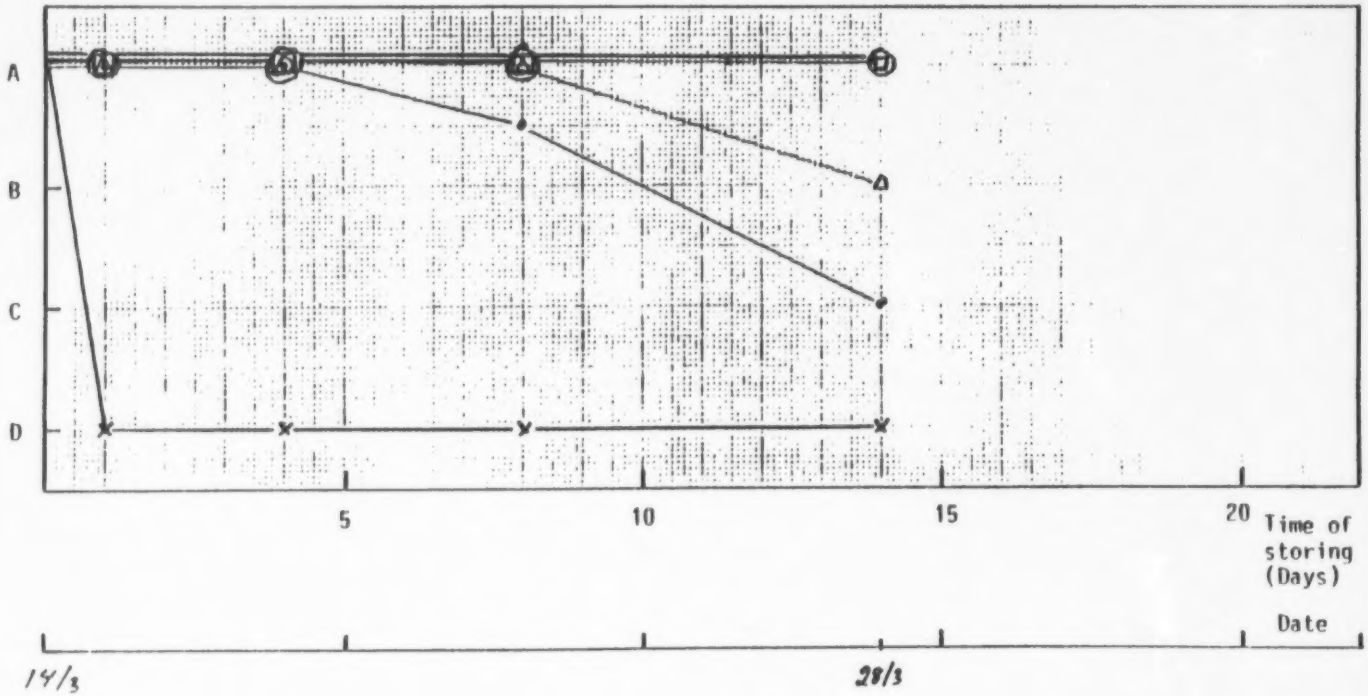
COAL	STABILIZER	DATE/SIGN
Coal Creek CCO-242/243	Carbofix C-13	850314/H.M.
ADDITIVE CONC. Carbofix 83: 5.0 g/kg coal	NOTE:	TEMP:

g Carbofix C-13 per kg dry coal in the fuel

×	0
•	0,41
△	0.55
□	0.69
○	0.83

SCALE

A. No Sedimentation
B. Sedimentation tendency (Gradient)
C. Soft Sediment
D. Hard Packed Sediment

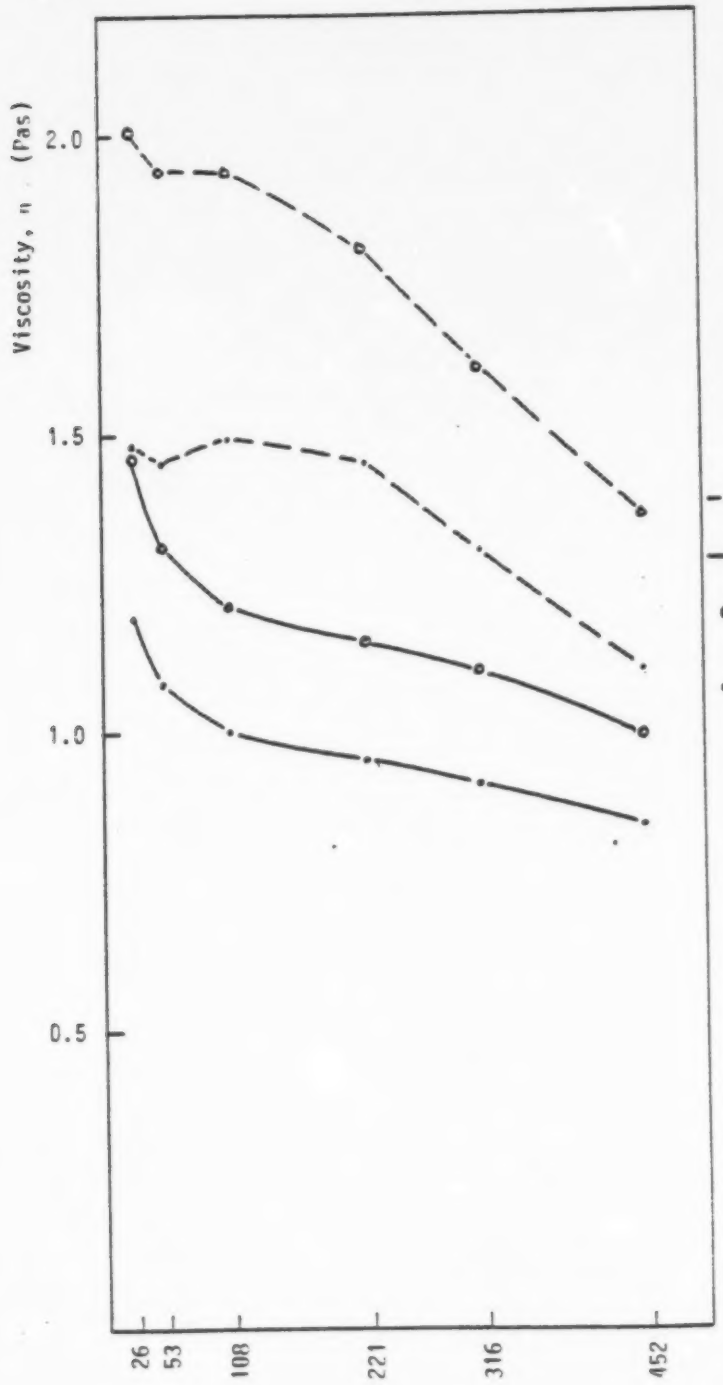


Carbogel

THE INFLUENCE OF THE SHEAR RATE ON THE VISCOSITY

Diagram 29

COAL	DATE	NOTES
Coal creek	850328	Stabilized fuel measured at two different points of time
MEASURING SYSTEM	SIGN	
DIN - 125	H. M	



Note:
-Dispersants
-Solids content
-Density
-Stabilizer
-Others

SC ~ 72.4 %

5g Carbofix B3/kg coal

---/ day after preparati

——/6 days after preparatio

o 0,69 g Carbofix C-13 per kg coal

• 0,55 g Carbofix C-13 per kg coal

APPENDIX 2

MARCH 1984

ENGLISH CHINA CLAYS

ST. AUSTELL CORNWALL

ENGLAND

FOR WESTAR MINING

B.C. RESOURCES GROUP

VANCOUVER BRITISH COLUMBIA

CANADA

(A) COAL/WATER MIXTURE FUEL PRODUCTION FROM SUPPLIED COAL SAMPLES

(B) MINERAL BENEFICATION TRIALS ON PROCESS WASTE MATERIALS

COPIES : WESTAR MINING (3)
ENGLISH CHINA CLAYS (7)

INTRODUCTION:

Following visits by Westar Mining to Cornwall and English China Clays to Vancouver, Westar Mining agreed to send a variety of coal samples for evaluation. Two types of evaluation trials were to be carried out by English China Clays, (1) to produce coal/water mixture fuels and (2) to beneficiate samples of various process waste streams with a view to increasing the overall coal recovery as an acceptable product.

Seven samples of materials were received in Cornwall from Westar Mining, two coals samples for the coal/water mixture fuel production and five small samples of various waste streams. The specifications of Westar Mining's product coals and indications of the analyses of the two mined coal samples were also provided.

The coal samples were processed in the Central Laboratories of English China Clays using our developed standard beneficiation and coal/water mixture production techniques. This report describes the test procedures used and gives the process results, and final coal/water fuel properties. All these results are then discussed.

TEST PROCEDURE

(a) Coal/Water Mixture Production

Two samples of candidate coals were received from Westar Mining.

(1) ex Greenhill Mine

(2) ex Coal Creek Mine

Both samples were analysed initially the results are given in Table 1.

As these trials were only exploratory and indicative no optimisation tests were carried out and each coal was treated in an identical manner.

The coal sample was crushed and wet ball milled. The mill product was classified at 75 microns using a vibratory screen.

The -75 micron mill product at 20 to 25% byweight solids level was beneficated using a two stage flotation process to remove the released impurities (ash content). Laboratory scale English China Clays flotation cells were used for these tests. Samples of the float and sink fractions from each stage were taken and analysed.

The process results are given in Table 2.

The final float product (the cleaned coal) was then dewatered using the English China Clays high pressure filtration equipment to provide a filter cake moisture level of <30% by weight.

This cake was then used to produce the coal/water mixture fuel.

The properties of the coal/water mixture fuels were determined.

The results are given in Table 3.

TABLE 1

WESTAR MINING, VANCOUVER, BRITISH COLUMBIA

CANADA

Feed Coal Samples

	Greenhill Mine	Coal Creek Mine
Ash content % by weight	7.8	8.2
Volatile Matter	-	23.2

TABLE 2

WESTAR MINING, VANCOUVER, BRITISH COLUMBIA, CANADA

PROCESS RESULTS - FLOTATION TESTS

Sample	% w/w Rec'y of original	Properties %Ash	%Volatile Matter	Particle Size Microns +53	+20	+10	+5	-2	-1
Greenhill Mine									
Feed -75 microns	100	7.8		3	18	58	78	8	6
Rougher Flotation Stage									
Float Product	94	4.8							
Sink (waste)	6	54.1							
Cleaner Flotation Stage									
Float Product	89	4.2		4	17	43	89	6	4
Sink (waste)	5	17.0							
Coal Creek Mine									
Feed -75 microns	100	8.2	23.2	2	36	58	92	5	4
Rougher Flotation Stage									
Float Product	92	4.4	23.9						
Sink (waste)	8	53.4	15.1						
Cleaner Flotation Stage									
Float Product	87	3.6	24.1	4	39	50	86	3	<1
Sink (waste)	5	18.2	19.6						

TABLE 3

WESTAR MINING, VANCOUVER, BRITISH COLUMBIA, CANADA

COAL/WATER MIXTURE FUEL - PROPERTIES

		Greenhill Mine	Coal Creek Mine
Composition			
Coal % by weight		71-72	73-74
Additives % by weight		1-2	1-2
Remainder water			
Ash %		4.2	3.6
pH		8.4	8.6
Volatile content		-	24-25
Particle Size of solids		-75 microns	-75 microns
Viscosity at 20°C			
Brookfield	10 rpm	9.5 poise	20.0 poise
	20 rpm	7.8 poise	16.5 poise
	50 rpm	6.1 poise	14.0 poise
	100 rpm	5.8 poise	13.0 poise
Ferranti	11.84 sec^{-1} shear rate	5.4 poise	10.7 poise
	50.67 sec^{-1} shear rate	5.5 poise	12.2 poise
	125.4 sec^{-1} shear rate	7.9 poise	16.9 poise

10-15 poises equiv to fuel oil.